The S-300 family

Now we are in the late ’60s. Around Moscow more than a decade ago have been built the S-25 Berkut SAM ring, then later SA-75 Dvina (SA-2A), S-75 Desna (SA-2C) and S-75M Volkhov batteries are built in ring formation around the most important and largest cities. S-125M Neva filled the low level gaps in the rings and from mid the ‘60s long range S-200A Angara (SA-5A) and S-200V Vega (SA-5B) systems are deployed.

In the early ‘70s against every type of threats was prepared the PVO both with SAMs and interceptor fighters either. The AGM-28 could be downed both at low level (slower) and high level with high speed profile at (17 km and ~M2.0), the B-58 Hustler and even the M3.0 capable B-70 Valkyrie and AGM-69 SRAM were not impossible targets at least for S-200 SAMs. PVO introduced the MiG-25 regardless the B-70 never entered into service in US.

The pace of rapid development of the Cold War did not stop which represented new kind of threats to the USSR. For the US leadership became evident strike with high flying intercontinental bombers against the USSR would be successful only if some targets are attacked simultaneously and even with this restriction the losses very likely could be very high.

For launching the AGM-86s (range was about 1200 km) from B-52s required to penetrate deep into airspace of USSR or WPACT to reach largest cities in European part of the USSR. The AGM-69 SRAM had much less range which meant more serious threat from PVO. Even flying at and very fast did not mean protection against the MiG-25 and S-200 Angara/Vega SAMs.

Even the engagement envelope/zone was restricted for all types of SAMs against high speed targets they could be downed. Against the few high speed attackers the PVO had considerable firepower. From the attacker (US) side it was pointless to further increasing the speed and altitude of bombers and missiles, within reasonable technical limitations and financial restrictions creating more powerful airplanes and missiles was impossible. Instead more powerful (regarding flight performance) bombers and missiles rather smarter weapons were needed.

The solution was creating such missiles which could fly autonomously at very low altitude and was possible to launch them far from the threats. For the PVO the most dangerous threat for late ‘70s and early ‘80s meant the air launched AGM-86 ALCM[1] then the sea, submarine and land based BGM-109 Tomahawk[2] cruise missiles. The AGM-86 ALCM could be used from the few new B-1B bombers but all B-52H and a part of older B-52 fleet also was capable to use it.

This meant very cost effective solution, instead creating very expensive fast and new bombers or high speed missiles. It was possible to create a totally different level of new attacking missile while existing platforms with minimal upgrades could use them. These cruise missiles used the new TERCOM guidance method it made possible fly autonomously at 30 meter or even lower above flat terrain. The B-1B could fly 60 meter using terrain following radar (TFR) combined with autopilot system. (It was not necessary if we consider the 2000-2500 km range of AGM-86 ALCM.)

[1] http://www.designation-systems.net/dusrm/m-86.html

[2] The air launched Tomahawk was tested but never entered in service.

It is a very subjective question why were needed the cruise missiles (with nuclear warhead) while thousands of land and submarine based warhead and hundreds of ICBMs and SLBMs have entered into service until the late ‘70s in US. The USSR abandoned the idea of using intercontinental strategic bombers against USA and Canada in the mid ‘60s because of ballistic missiles. USA did not follow this idea.

In my opinion developing the B-1 Lancer was pointless because it carried the same cruise missile as the B-52 fleet. Besides the ICBMs and SLBMs why would anybody feel the need of new type of weapons against cities?

Against ICBMs was not defense at all except Moscow which was protected by ABM system (which used and still use today missiles with nuclear warheads), and even this system had limited target channels and missiles. The AGM-86 and BGM-109 was much more suitable against exceptionally hardened and important military targets (top level air defense command posts, nuclear warhead storage sites, etc.) using them against cities is pointless. (Rationality in nuclear war is 0, let’s just forget this fact for a second.)

These new kind of weapons made possible to destroy even the most hardened surface targets. It does not exist any structure which is able to resist a 200 kt yield knocking on the door with only about 10 meter CEP. With these new cruise missiles the most crucial items of the key elements of the air defense and command post of the WPACT could be eliminated, moreover these new CMs were so accurate many times they could do this even without using nuclear warhead.

The note about usefulness and necessity the B-1B deserves a bit deeper explanation. Developing the B-1A started in 1969, it was essentially an “inflated” FB-111, which was designed a low level penetration bomber, so it was far better in this area then B-52 without TFR. The B-1A conception was killed by the fear of the MiG-31 which designed to be with “look down” and “shoot down” capability. The ATB program had to solve this issue which decades later leaded to the B-2A Spirit. The B-1B designed only for an interim solution and because of this initial aim only 100 pieces were manufactured to fill the gap until the arrival of the product for ATB program. Were big arguments about B-1 program on different level of leadership of US but was some sense behind the concept.

The theoretical M2.0 top speed of the low level B-1A very likely came for the usual mania of USAF, which always had compassion for high top speed (even in most of cases it has 0 tactical usefulness and in most of cases never could be reached in real situations.) The passion for M2.0 was changed after experience of Vietnam which had strong impact on specifications of B-1B. The inlet of B-1B got deflector to reduce the radar cross section, but this change resulted much less top speed, the top speed of B-1B was only M1.2 even at very high altitude, initially at very low level was this top speed demand.

After the Cold War B-1B fleet lost its original role, during the Cold War only used as nuclear weapon platform, while today is a conventional bomber with precision strike capability with JDAM bomb family, AGM-154 JSOW or AGM-158 JASSM or even laser guided bombs. Also just a funny result of the Cold War that the gap filler B-1B fleet even after budget cuts still counts about 60 active airframe while the production of B-2A ended after 20th airframe and B-52H is still flying today. Is a good chance B-52 survives both of her successors.

Both the AGM-84 and BGM-109 are not high speed weapons their maximal speed at low level is only about 800-850 km/h (~M0.65). They meant radically different threat comparing to bombers with nuclear bombs or even with AGM-28 because of the following issues:

- Their small physical size means smaller radar cross section comparing to all other previous targets like bomber or the very large AGM-28. (Only the AGM-69 was comparable in size.)
- The altitude of CMs is only 30 meter or even smaller above flat terrain. This low altitude strongly restricts the engagement envelope because of the radar horizon. (For the MiG-31 or any other aircraft ground clutter is a new issue which should be resolved.
- The consequence of the low flying altitude was losing the area denial capability (against medium and high flying targets) by the S-200 SAMs. In fact even today (2018) is no such SAM system which can provide area denial capability against low flying targets. Even after introducing the first S-300PT the maximal engagement range against low flying targets dropped close to maximal range of S-75M Volkhov /S-25 Berkut, about 40 km against med flying targets.

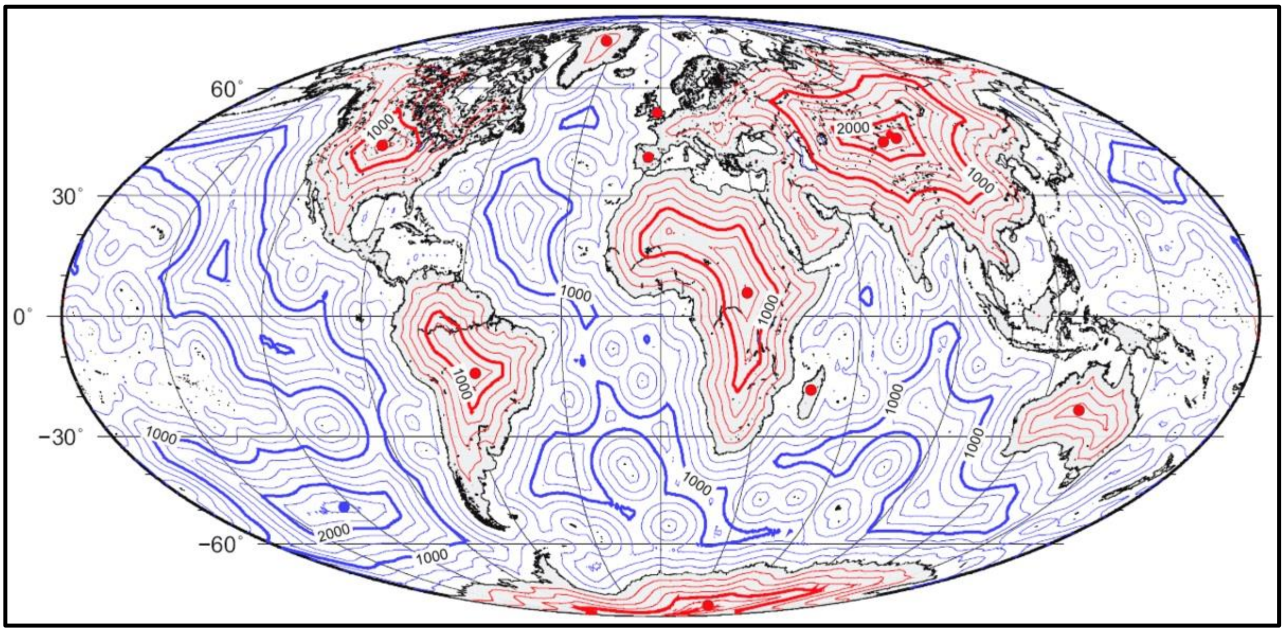
  The defended cities or objectives had to be defended again with the circle style deployment formation as with S-25 around Moscow or as did with S-75/S-125 for Leningrad with this very expensive new SAM type. The new cruise missiles literally annulled all the previous efforts of the PVO. Because of the very small engagement range, the circle style deployment it was not possible defending against low flying targets all potential targets, only the most important cities and military objectives could be defended because it was financially impossible do defend everything. (The engagement zones of S-200 Vega batteries literally covered the whole European part of USSR.)
- The maximal launch range of cruise missiles could be 2000 km or even larger distance. Both CMs were capable to fly 2500 km which meant they could be launched far outside of range any SAMs moreover. With such large range CMs could reach Moscow and many other targets deep in the USSR even without flying close to airspace of USSR regardless CMs did not have to fly on the shortest straight line route to the target.

  Even the fighters of PVO had close to zero chance to intercept the bombers before the launching CMs even after introducing the MiG-31 which would be the best option for USSR. Even this issue from the late ‘70s the MiG-31 Foxbat represented the area denial capability instead ground based SAMs. The S-300 against low flying targets meant only point defense capability.

  (The classical point defense systems have much smaller range than 40 km, but in comparison with 160-250 km range of Angara and Vega 40 km could be treated as point defense.)

  To shoot down with fighters bombers would be possible only in case bombers from targets release about 2000 km away the CMs and targets are deep in the USSR. In other targets CMs theoretically could be released far above oceanic areas from 1000-1500 km the coast of USSR. It was way too few MiG-31 for this goal and at the end of Cold War only a handful of MiG-31 had aerial refueling capability. On the next page the maps shows literally all important region of USSR could be attacked with CMs far outside of airspace of USSR or WPACT, moreover the region where CMs could be launched mostly in polar region where was minimal or 0 radar coverage, outside of patrol areas of PVO fighters.

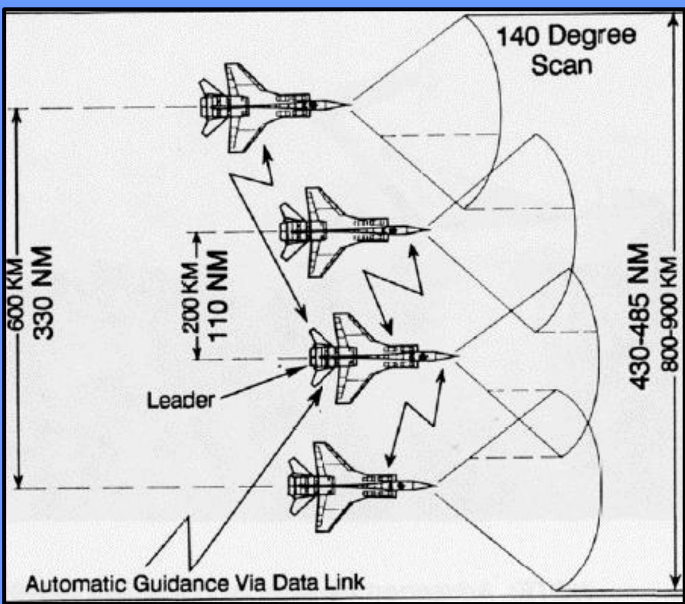
In case a nuclear was I have doubts about how would handle USA or USSR the sovereignty of other nations. Very likely the CMs would fly above other nations for example Pakistan or Iran therefore another attack direction was possible. Very likely these countries were not able to detect and track low flying CMs, shooting down was out of the question lack of capability.



Distance from the oceans in kilometers.

It is worth to say some words about MiG-31 because her capabilities are strongly bonded with S-300. In the most simplified way the MiG-31 Foxhound can be treated as a downscaled S-300 SAM battery. The difference it has much fewer missiles only 4xR-33 (AA-9 Alamo) and lack of 360 search capability which was supported forS-300 regiment of brigade by the Big Bird (5N64K RLO) radar (see later). The MiG-31s supported with digital data link in line formation could scan a large area for finding and down the CMs. Interestingly the scan azimuth limit of the Zaslon radar is 140 degree comparing to the 105 degree of the Flap Lid (5N63 RPN) fire control radar of S-300PT. (See later.)

MiG-31 was the first Soviet fighter with reliable look down/shoot down capability; moreover it had the first ESA type (PESA) radar in the world. The benefit of using MiG-31 to neutralize the limitation radar horizon but it had the price; the CMs in most of cases had to be found with radar in ground clutter.



The engagement range of MiG-31+ R-33 at high altitude initially was larger than S-300 system until the arrival of S-300PMU1 and 48N6 missile (see later) in the early ‘90s.

The MiG-31 was really effective only with A-50 Mainstay AWACS airplane which in the time collapsing of USSR was not available with enough numbers and was very far from a matured and usable status. (See previously.) Essentially the A-50 had to provide for MiG-31 flights the 360 degree search capability similarly as did for S-300PT with the Big Bird long range EW radar and the 55K6 command post.

Regardless of MIG-31 it did not mean SAMs did not have to prepare for the new kind of threat, because nobody expected that fighters could down all the CMs. The CMs which bypassed through MiG-31 defensive CAPs have to be downed by the SAMs.

In the ‘70s the only effective SAM in theory was the S-125M Neva considering minimum engagement altitude limitation and neglecting all other operations factors – such as reaction time and other target parameters – which in reality would seriously reduce the effectiveness of the Neva. Only problem around Moscow never was deployed any Neva SAM batteries. Even if Soviets had assumed reliable low level engagement capability against CMs just for filling the gaps of S-25 Berkut SAM ring would required insane amount of S-125 M batteries.

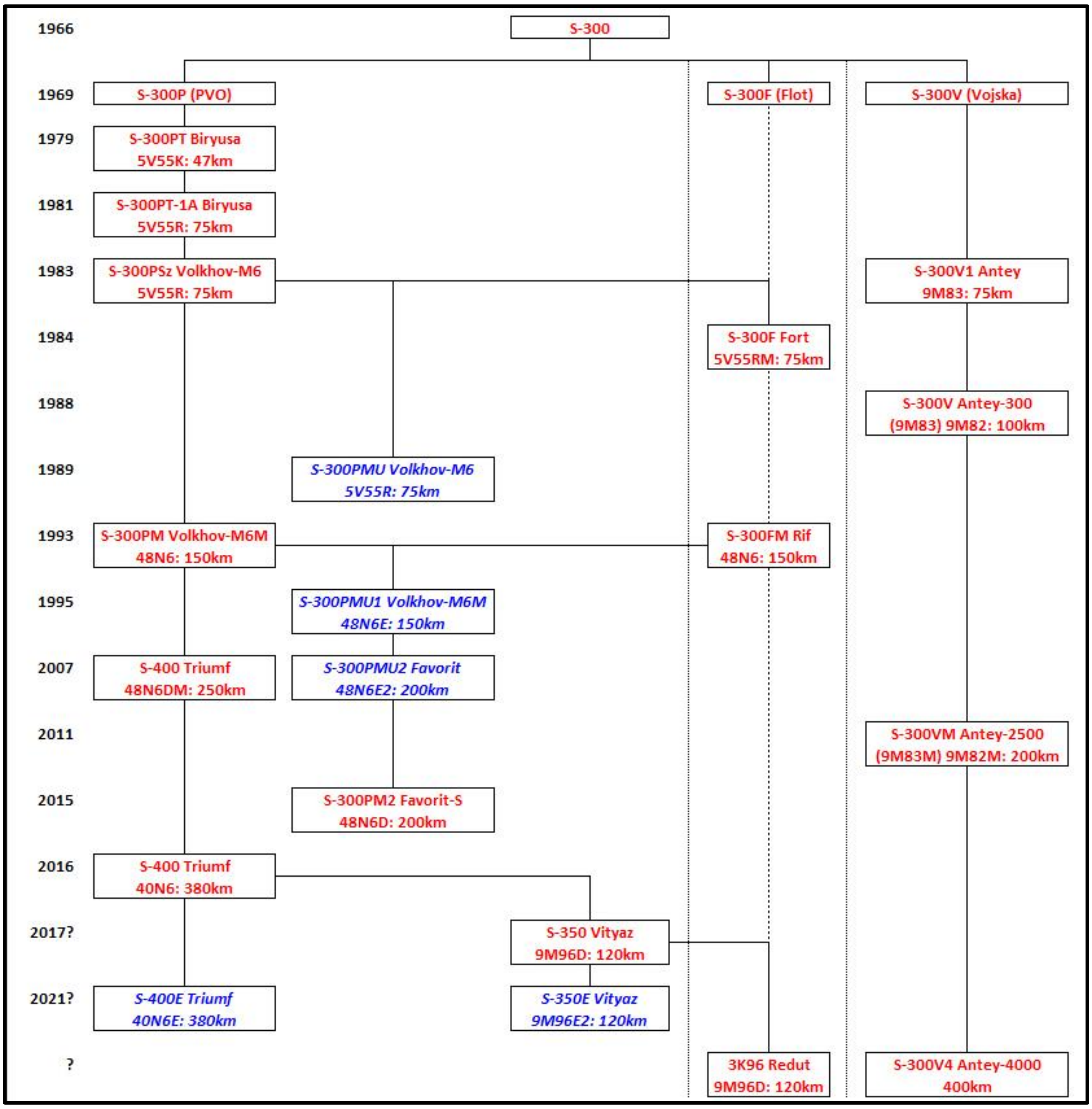
A single bomber could launch 8-20 pieces of CMs within 1-2 minutes, therefore lots of incoming targets had to be considered as a threat in a very small airspace. Even with CMs the best way is try to penetrate/bypass the air defense in one or two locations to reduce the time window for destruction. A single target channel of a Neva battery was simply was not enough to stop such massive CM attack. For every one target channel one Neva battery had to be deployed.

The inner Berkut ring included 22 batteries (regiments), assuming 6 target channels – S-300PT had six – without any reserve with minimal or no engagement zone overlapping 132 Neva batteries were needed just for the inner ring only with 20 km engagement range. Obviously this approach showed the need the different way of approach to solve the problem.

A goal was creating a SAM system which is capable to destroy targets at very low level (30 m or lower) even such targets incoming in massive scale. This base demand meant the new type of SAM had to have multiple target channels. But designing only for a single goal a totally new SAM system would not be economical the new SAM system had to have the same engagement range at least the S-75M Volkhov against medium and high flying targets. With these specification demands in first step was possible to replace the S-25B Berkut, S-75M Volkhov and S-125M Neva around Moscow and larger cities and key military installations such as Vladivostok or Murmansk naval ports.

The goal in longer perspective was much more ambitious, not only the S-25M, S-75M and S-125M but even the long range S-200 family had to be replaced with an S-300 variant. This was not a simple task therefore very wisely leadership selected the step-by step development, not with a single big leap tried replace all SAMs. In that time nobody thought how much time will pass to reach this original goal.

The diagram on the next page serves the easier understanding the evolution of S-300 SAM family. On the evolution three besides the PVO S-300 also the S-300V is included regardless it was a totally different branch, it is front level, long range, mobile army air defense system, it was developed a different design bureau. S-300P family was developed by Almaz, the S-300V was developed the Antey. (Today these two bureaus are integrated into a single bureau.)



Above is the evolution tree of S-300P and S-300V family.

Regardless only the P and V letter different these two branches represent totally different design approach. They never share any radar of missile; they do not have even the same guidance. S-300P is designed for PVO (homeland air defense), S-300V is designed to for army air defense. Initially for S-300P family ABM capability was not goal just later got this feature, while for S-300V against older TBMs and even for the very advanced and powerful Pershing 2 ballistic missile also had to be countered. During the design of the S-300P experiences of Vietnam conflict was taken in account:

- The enemy has the air superiority, the goal is defending a city or smaller region, many times the “hit and run” tactic were needed. This kind of approach was important for 3rd world countries in good relationship with USSR. Both in USSR and WPACT countries S-300 batteries were deployed or planned to be deployed into fix locations.

- 360 degree coverage was specified with very short relocation time. The 360 degree coverage concerns of long range EW radar, the azimuth limitation still exist for fire control radar as for the older SAM systems, but the limitation is much more restricted.

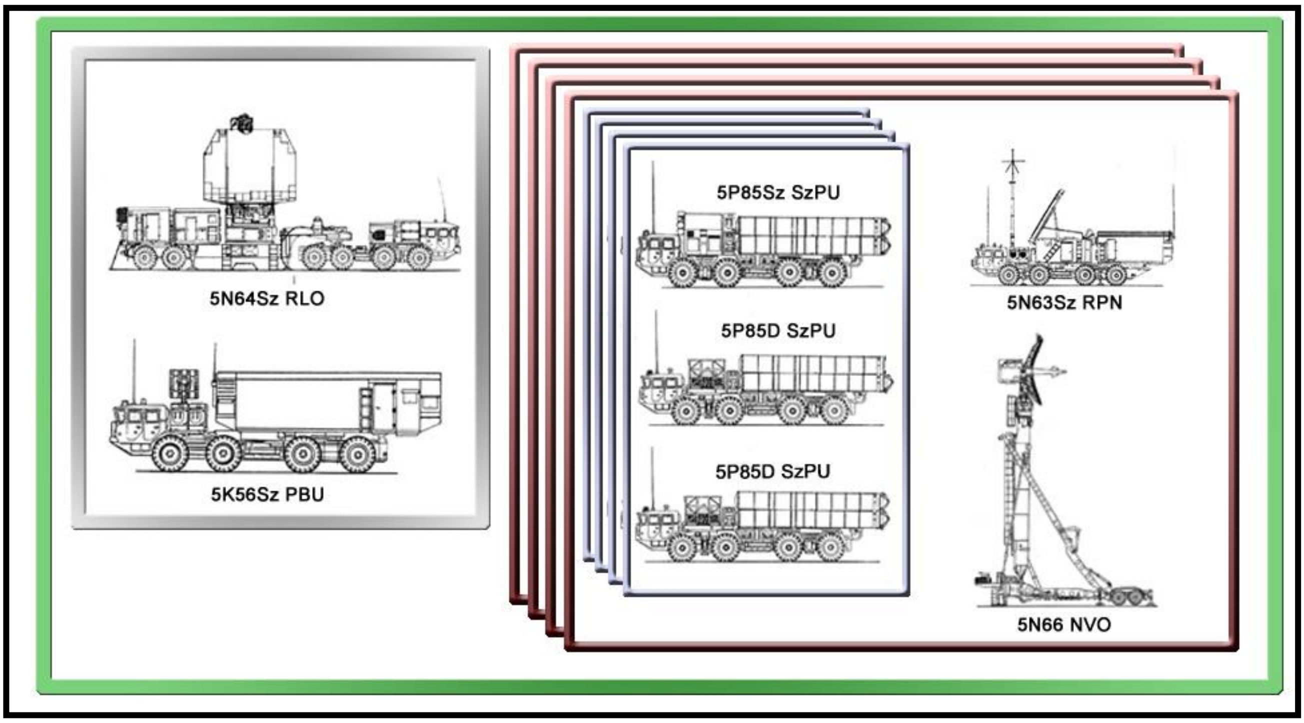
- For a single missile battery is different radar types are required for search and fire control, not mentioning the whole SAM regiment or brigade.

The new kind of threat by the CMs made so urgent deploying the new SAM system for the first S-300PT variant the mobility of the system was sacrificed. Instead self-propelled vehicles on towed trailers were installed the launchers and many other elements of the system. Deployment of S-300PT (SA-10A) started in 1978 with5V55K missiles around Moscow. Between 1978 and 1983 56 S-300PT missile batteries were deployed around Moscow, each S-25 Berkut regiment was replaced by a single S-300PT missile battery. In total 56 batteries were deployed. The 5V55K missile used pure radio command guidance (RCG), which limited the maximal engagement range to 47 km; the minimal engagement altitude was 25 meters.

The composition of the S-300 system in some area was not different from previous PVO SAM systems. The S-300 also had different type of radars for different purpose, but the role of radars was a bit different from previous SAMs. To understand the operation principle the S-300 SAM system the organizational structure of and S-300 regiment/brigade has to be known.

The missile batteries of the S-300 were assigned into regiments or brigades. A single regiments consists 1-4 missile batteries and 1 commanding battery, one brigade consists 5-6 missile batteries and 1 commanding battery. Around Moscow 56 batteries were deployed which means could be S-300 brigades with 5-6 missile batteries and also regiments with 1-4 batteries.

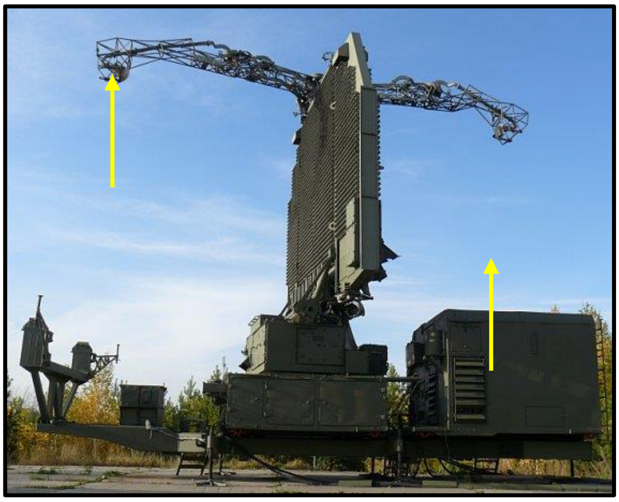
On the diagram below is the composition of and S-300PS regiment with 4 missile batteries for easier understanding, the image consists only the main items of the regiment. (In the attachments and later are more items are listed.)



Above is an S-300PS battery with x4 missile batteries with the command battery. Only the main items of the regiment are displayed, the radars and missile launchers. The x4 missile batteries are marked with red border, the x4 launcher sections are marked with blue border. Each missile battery has x4 launcher sections. The S-300PS regiment is built up from 4 missile batteries (green border.)

Each S-300PT regiment/brigade had three different kinds of radars:

- Each missile battery had 1 x 5N66 NVO (Clam Shell) radar, 360 degree mechanical scan, low altitude search radar.
- Each missile battery had 1 x 5N63 RPN (Flap Lid) fire control radar.
- Each missile regiment / brigade had 1 x 5N64K RLP (Big Bird), 360 degree mechanical scan long range EW radar with PESA scan in elevation.



Comparing to S-75/125 SAM S-300 was different because only the regiment or brigade has long range 360 degree scan EW radar not each missile battery. The 5N64K RLO (Big Bird) served this purpose, see the image on left.

The RLO has the same role as the P-12/18 (Divina/Volkhov), the P-15 (Neva) or the P-14F (Vega) radar, the 360 degree search and long range target detection to provide the situational awareness for the missile batteries. The detected targets by the RLO are classified by the command post (5K56 PBU, F9 cabin) of the regiment/brigade, medium and high flying targets are selected and forwarded to missile batteries from the command post in normal cases.

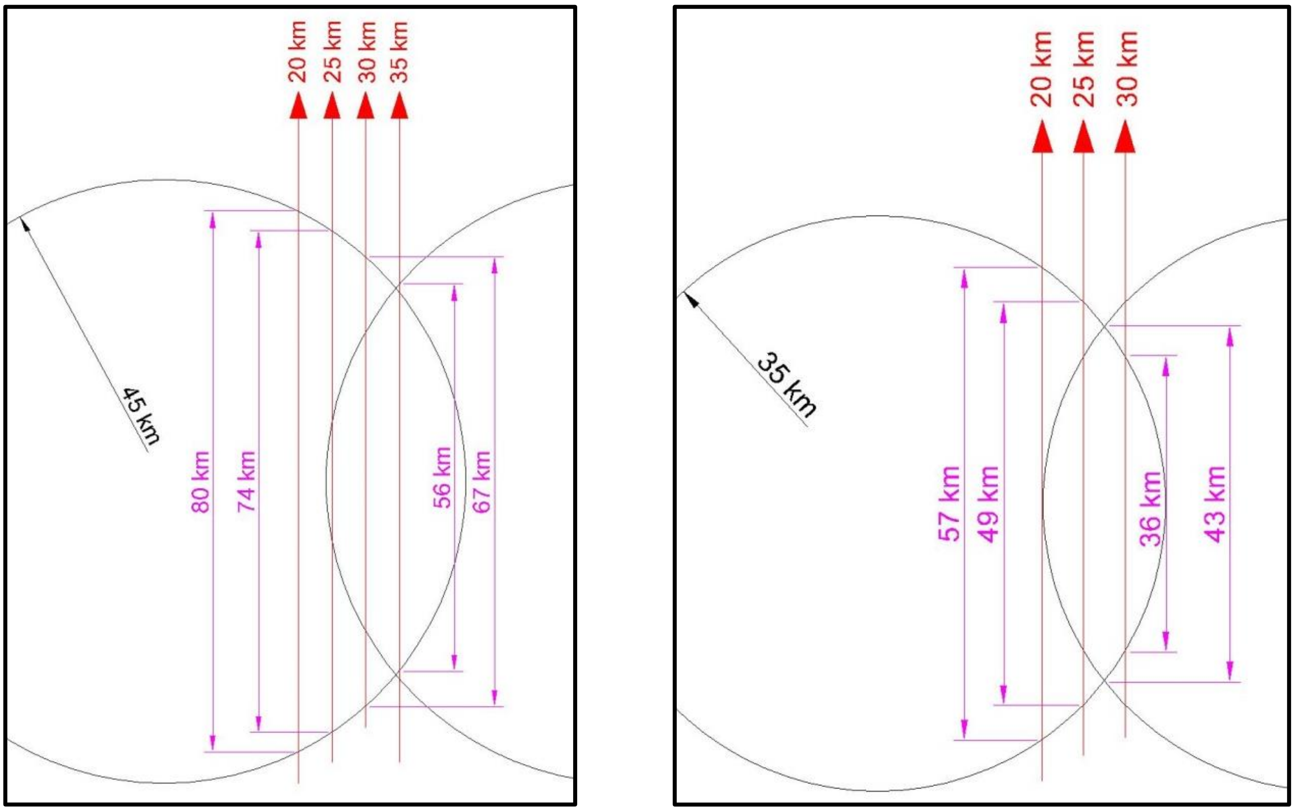
The unique feature of the RLO it scans with two radar beams which means with the same rotational speed has double refresh rate comparing to conventional radars. From both sides two emitters (marked with yellow arrows) illuminates the PESA phase array while rotates the antenna. Comparing to the mechanical rotational speed the ESA scan is much faster, so it is possible to scan in elevation while in azimuth the mechanical rotation provides the scan. With this feature Big Bird can measure target altitude very well comparing to older P-12/P-15.

Even only the whole missile regiment or brigade has a 360 degree long range EW radar does not mean a single missile battery cannot search autonomously, but this self-search capability has very strong limitations.

Against low flying targets (practically CMs) each missile batteries have their own low level, continuous wave (CW) 360 degree scan radar, the 5N66 NVO (Clam Shell). Because the horizon limits the detection range the radar was installed on a mast. (See on the image on left side.) The rotational speed of NVO is 20/min, which means very quickly can be tracked the detected targets and track/plot can be calculated.

With increase of the elevation of the radar antenna against targets at 30 meters altitude the maximal detection range increased from 35 km to 45 km considering ideal conditions (totally flat terrain without obstacles.) At first sight this does not seem a big leap forward bit with big offset target distance strongly increases the time for target tracking for engagement.

On the schematic drawings below 10 meter fire control radar (RPN/Flap Lid) and 30 meter NVO antenna elevation were considered. Idealized detection and engagement zones are displayed considering totally flat terrain without obstacles. It is clearly visible how important was increasing the detection range with 10 km because it provides the necessary additional time for target classification, RPN has time to track target and guide missiles to targets before they left the engagement zone/envelope. (Offset distance values are shown above the assumed straight flight path of cruise missiles.)



Impact of antenna installation elevation in detection range with NVO (left, target tracking capability of RPN (Flap Lid) on right considering idealized terrain.

On the image left is show the fire control radar of S-300PT, the 5N63 RPN (Flap Lid) (or F1 cabin). Instead of mechanical scan method Flap Lid had for both azimuth and elevation scanning a passive phased array antenna, was PESA type radar.

Using the data of the regiment/brigade command post and the Big Bird radar the RPN illuminated and tracked the target with 1 degree wide beam, the radar was capable to form and emit narrow pencil beam hundreds of orders/second. This very fast scan and free scan pattern capability both in azimuth and elevation made possible to track multiple targets within 105 degree azimuth which was required to ensure simultaneous engagement capability.

Comparing to older mechanically scanned radars the RPN is capable to track and illuminate targets without any azimuth and elevation limitation within the maximal azimuth and elevation limits. After targets have been locked and tracked by the data of the command battery and Big Bird radar tracking is possible with short interval target illumination which provides the data for missile guidance. With of many short interval illumination target flight path and collision course

can be calculated. (The radar scan not only the detected targets but also close proximity of target to make predictions and make easier the target tracking and also has additional feature because of this method, see later.)

During missile guidance RPN is set to a fixed azimuth position and target tracking is possible within 105 degree in azimuth, but the RPN anytime can be turned left or right to a different direction if it is necessary. The RPN can be turned to left or right but it cannot perform a full rotation. It can be turned to (for. ex.) 200 degree left or 200 degree right to centerline, but is not possible to turn into one direction 360 degree not a single time, continuous rotation is not possible. The RPN is not designed to be long range EW radar, therefore it not possible to use 360 degree scan, only sector scan is possible.

At this point is worth to compare the RPN/Flap Lid to the Yo-Yo antennas of S-25 Berkut. For S-25 two Yo-Yo antennas had to be rotated with quite fast speed (mechanical scan) both in elevation and azimuth angles. The side effect of this solution was the whole engagement zone was scanned for achieving the necessary refresh rate to use the 20 target channels of the Berkut regiment. Regardless if we have detected all the targets in the scan limitation of the radars for continuous target tracks it would be enough just scan the proximity of the targets but with mechanical scan this kind of selective scan is not possible while the RPN/Flap Lind radar is able to do this. But RPN has this capability only with a single non rotating antenna which is mobile.

The capability of Yo-Yo antennas would be great if anybody wish to provide anti-ARM capability because the within angle limitations of the antenna the whole airspace is scanned not only location of possible launch platforms. Only problem with antenna size of Yo-Yo creating a mobile SAM system is impossible because of size and weight limitations. Comparing to the whole zone scanning the RPN scans the detected targets and their proximity very frequently to detect missile launches, same detection was possible even with Stone Age Dvina (see in earlier chapters) but only against the one tracked target.

Comparing to Yo-Yo the RPN was much more “intelligent” radar but this kind of intelligence resulted partial blindness comparing to Yo-Yo considering anti-ARM capabilities. If an ARM launched below the horizon and no other radar (such Big Bird or NVO, NVO sometimes is not available, see later) does not detect it the RPN never will track the ARM because it has no idea where should be start the search.

One Yo-Yo antenna could scan 60x60 degree zone while the RPN even a fixed RPN setting had at least 105x60 or even larger scan zone and with RPN turning capability can fire not only outwards of the SAM ring around Moscow but in any direction. So in general the RPN was much more advanced than any other PVO fire control radar previously, its limited self-search capability also was better comparing to SNR-75 Fan Song radar of SA-2 or SNR-125 Low Blow radar of SA-3.

(The anti-ARM capability was not important for USSR in most of locations because only tactical fighters could carry, so was not ARM threat. In WPACT countries and some coastal cities and naval ports ARM threat was not theoretical.)

So for S-300PT with RPN was possible to provide the necessary data for simultaneous target engagement but for the missile guidance also had to be provided the technical background. The S-300PT used pure RCG guidance, but was different from S-75/125, similar to cell phones used time-division multiplexing.[3]

[3] https://en.wikipedia.org/wiki/Time-division_multiplexing

Combination with RPN and such guidance even with pure RCG the S-300PT had 6 target and 12 missile channels.

Experiences of the Vietnam conflict, the predicted target quantity and short time window demanded larger missiles quantity in ready to be launched state comparing to Dvina or Neva (Neva was not used by NV), otherwise the 6 target and 12 missile channels would be pointless. Comparing to 6x1 of S-75 Volkhov and 4x2 or 4x4 missiles of S-125 Neva on rails a single S-300PT missile batter got 48 missiles. The main items of a missile battery were the followings:

- 4 pcs. 5P85PA launcher sections (пусковой комплекс), each launcher section had
  - 1 x. F3 cabin (аппаратный контейнер),
  - 3 x 5P851 PU towed rocket launcher (KRAZ-260) (буксируемая пусковая установка),
  - each rocket launcher had 4 x 5V55K (47 km) later 5V55R (75 km) missiles (зенитная управляемая ракета)

A single missile battery had 4x3 = 12 rocket launchers, so the total missile quantity without reloading was 48 missiles. The design and storage method of the missile was different was all previous PVO SAM systems. The missiles were stored into containers instead of rails; this conception was so new that only the 9K33 Osa AK and AKM variants used (short range mobile army air defense system). The container (tube) laid down on towed launchers in transported state, only in deployed state were erected vertically the tubes.

The missile is single stage, solid fuel propelled, was not necessary a booster stage comparing to any other older PVO SAM except S-25, but missiles of the Berkut used liquid fuel. With solid fuel handling the missile was as practical and easy as with S-125 Neva but without the necessity of the booster stage. The 5V55K or 5V55R missile had almost the same size as missile of Neva but with much better kinematics. (Regardless of same size the missile weight is roughly double.) So the new missiles of S-300PT united all the good properties of Berkut and Neva, while discarded all the bad features of Volkhov , Neva and Vega. It was a really big leap ahead.

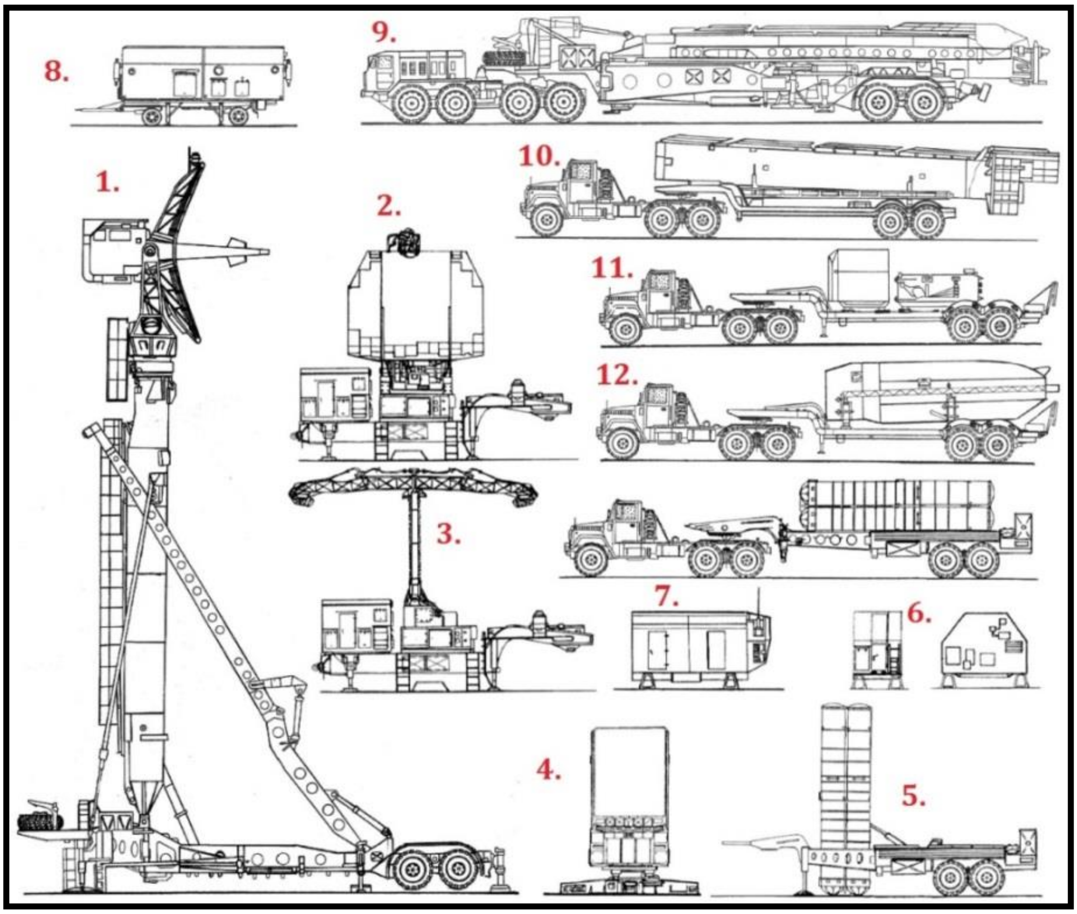
The solid propellant and the container storage made much easier the handling and maintenance the missiles, also had positive impact on missile life span. Missiles are launched from the vertically standing container. The gas catapult system throws up the missile about 20 meters then then ignites the rocket engine; the burnout time of the engine is about 10-11 seconds. Depending on the flight path of the missile the burnout speed is about 1.8-1.9 km/s (~Mach 6.5). The maximal target speed against non-jamming targets of S-300PT/PS/PMU was 1.2 km/s (~Mach 4.0). The missiles of S-300 represented a new missile generation not only because the handling and maintenance, but also in terms of combat capabilities.

The 5V55K used pure RCG which restricted the engagement zone in distance to 47 km because as the target distance increasing as the measuring error does the same. Above certain missile speed and target distance without using nuclear warhead destroying target reliably is not possible. Later we can see comparing to 5V55K more advanced missiles of S-300 are not larger or considerably heavier, the engagement zone became larger because of different guidance (RCG ---> SAGG) and radars for the later developed S-300 variants. The kinematics of the missile literally did not change at all.

Even the first 5V55K (S-300PT – 1978) missile had the same burnout speed (1,9 km/s) as the 48N6D missile (S-300PMU2 – 2004) 25 years later but the maximal engagement range increased from 47 km to 200 km. The burnout speed defines much higher kinematic range than 47 km. If the S-300 was a ballistic missile it would have about 400 km range which such burnout speed. The very high burnout speed meant both advantages and disadvantages in combat capabilities; see later at the engagement zone.

After mid ‘80s the 56 missile batteries of S-300PT were upgraded to S-300PT-1A which made possible to use the new 5V55R missile. This new missile rather pure RCG had SAGG guidance, the maximal engagement distance increased to 75 km.

On the diagram below is the equipment of S-300PT missile battery with the Big Bird radar of the command battery, the command post is not displayed on the diagram.



Above are the main items of 70R6 Sz-300PT Biryusa (SA-10A).

1. 5N66 NVO (Clam Shell) low level 360 degree search radar (F5). Each missile battery has 1 pc.
2. 5N64K RLO (Big Bird) 360 degree long range EW radar (medium and high altitude search radar for the regiment/brigade) (F6). Only the command battery has 1 pc.
3. See at 2. (side view)
4. 5N63 RPN (Flap Lid) fire control and missile guidance radar (F1 cabin). Each missile battery has 1 pc.
5. 5P851 PU launcher. Each missile battery has x4 launcher sections, each section with x3 launchers, each launcher with x4 missiles. Missiles could be 5V55K (PT), 5V55R (PT-1) or 5V55S (nuclear warhead) or combinations of these.
6. F3 AK launcher section command cabin, each launcher has 1 pc.
7. F2 KP combat command cabin, each missile battery has 1 pc.
8. 5I57 PDE Diesel-electric generator.
9. 5N66 NVO radar in packed state, see at 1.
10. Same as 9.
11. Same as 9.
12. Same as 9.

The regiment/brigade command battery of S-300 system is extremely important considering the combat capabilities of the missile batteries. (Except the PMU variant, it does not have command battery, see later.) The 5N83S command system has the following main items:

- 1 pc. 5N64K RLO (Big Bird) radar. Nominal range 300 km (against fighter sized targets). (F6, F7, F8 cabins) (радиолокатор обнаружения)
- 1 pc. 5K56 PBU regiment/brigade command post (F9 cabin) (пункт боевого управления)

For the missile batteries of S-300 above the low level zone at medium and high altitude the command battery provides target coordinates by the RLO (Big Bird) radar. Using target coordinates from commanding battery the RPNs (Flap Lid radar) of missile batteries are able to find and track targets very quickly. (On the image left 54K6E command post is visible, part of the Greek S-300PMU1.)

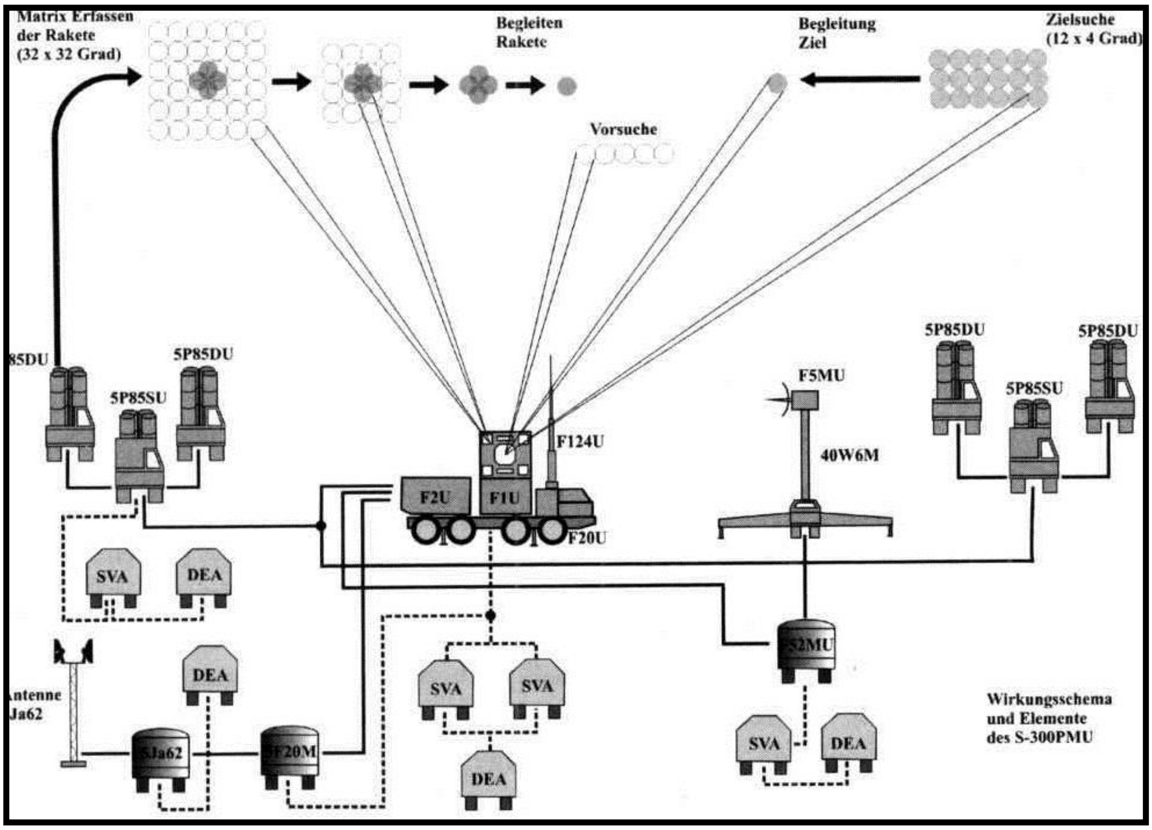
The missile batteries have only low level, 360 degree self-search capability be the NVO (Clam Shell) radar, each missile battery fill out their situational awareness. The Big Bird radar because of its position cannot provide the necessary low level coverage for missiles batteries because of the radar horizon. The missile batteries do not get all the coordinates of the detected targets from the Big Bird, the command post forwards only the targets which have to be engaged by the assigned missile battery, they do not have any information about the bigger picture. Besides the forwarded targets missile batteries have only the information what they NVO provides or in case of emergency using the RPN in sector search mode. This is totally opposite comparing to how the American Patriot system works where the ECSs of FUs (firing unit) can get the coordinates all the detected targets from any FU, not only targets which are assigned for engagement.

The RLO was simply too expensive to provide for each missile batteries and very likely was simply not necessary. The price of the command battery was about 2/3 or a missile battery, command battery price was 10 million ruble, the missile battery cost 14 million.

Without the RLO (Big Bid) the combat capabilities of missile batteries is considerably reduced because both NVO and RPN radars were not designed to provide full 360 degree search capability from low to high level targets. The RPN is not able to rotate while the RPN can use only for low level search.

The RPN is capable to search with 4x12 and 1x105 degree search pattern, the latter is used for low level search. Regardless the RPN can be turned left-right the refresh rate even in sector search mode is not as good as wit Big Bird radar. The big problem with this kind of search it make vulnerable to SEAD the S-300 because the RPN uses cm wavelength which can be used by the AGM-88 (even on back and side lobes). Using the RPN to search is a very bad idea in case SEAD operations are expected.

The regiment/brigade command post is automatized, it sorts and classifies the target and recommends targets for engagements for the operators similarly to the Patriot system, of course the operator can assign different targets manually for missile batteries.



Above are the different types of search mode options for the RPN radar in case S-300PMU (missile) battery.[4]

Above is the regiment/brigade command post. Are 6 operator stations, each operator can forward target coordinates for one missile battery. On the image above is the command post (PBU) of the S-300PM, not the PT/PS.

At this point is worth to compare to each other the operation principles of S-300 and Patriot systems. The battalion command post of the Patriot (ICC) is able to take over the control of any FU in the battalion using ECS of the batteries the S-300PT/PS cannot do this. The command post send only commands to missile batteries, can order to turn different direction the RPN or any other action via radio but command post does not have any authority above the missile batteries directly.

Another difference between Patriot and S-300 is the communication. Within a Patriot battalion FUs can communicate with each other without the battalion level ICC while for S-300 data stream is possible only

[4] Der Fla-Raketenkomplex S-300PMU in der NVA, page 89.

via command battery. The communication with later introduced A-50 AWACS is also possible via regiment/brigade command post.

It is also the result of different design approach that Patriot operators in ECS the FUs can see other targets than detect themselves, the whole radar picture can be shared with other FUs. For S-300 is no matter how many targets are detected and tracked by the Big Bird radar the missile batteries get only the assigned targets instead of the whole radar picture.

The S-300 was much more mobile than S-75/125 systems – even it was designed for PVO – but with restrictions because of the radars and data link to automatized command systems (IADS). The restrictions are the followings:

- In case the missile battery relies only on RPN for low level target search the battery is combat ready after 5 minutes. The RPN has telescopic antenna which provide the data link to command battery and can get target coordinates of medium and high flying targets. In this setup the low level capability of the missile battery is limited because lack of NVO which requires more time than 5 minutes. Low level search is possible with RPN but only with 105 degree sector search and high risk in environment where SEAD with AGM-88 (or similar "all aspect" ARM) is likely. [5]
- The deployment of the 5Ya62 (5Я62) antenna system required 45 minutes for the S-300PMU export variant, this system was needed to link the missile battery to automatized command posts (on any level). For WPACT countries only the PMU variant was available without the commanding battery of S-300 and RLO (Big Bird) radar. Because of this change in equipment and organization structure the PMU missile batter has 360 degree, EW radar the ST-68U (Tin Shield) which requires the same 45 minutes to deploy. Because of these factors the PMU has even worse mobility than the S-300PS. In case the whole missile battery relocated until 45 minutes after starting the deployment only the RPN was available for search (after 5 min) with sector search capability and was no data link at all.
- Deploy time of NVO (Clam Shell) radar is 90 minutes, against low level target only after 1,5 hours reaches the missile batter the full combat capability. It is no difference between the PMU and Soviet/Russian variants in this restriction.
- In case the command battery is relocating the whole regiment/battery loses the best long range 360 degree scan EW radar, the RLO (Big Bird) is missing. Without the RLO the combat capability of the regiment/brigade is seriously reduced because all missile batteries have to use RPN, they can provide only sector search. Therefore the mobility of the S-300 mostly means missile batteries moves around the command battery within certain limitations if they wish to keep the best available source to get target coordinates without using the fire control radar. When the command battery moves it is defenseless alone, the missile batteries have to cover it but with limited search capability.

  (Of course finding a non-emitting moving vehicle group is not as easy as it sounds. Today at least some S-300/400 units have the Pantsir-S1 (SA-22) system to cover firing batteries of the command battery against possible threats in this case or even against ARMs in deployed state because the firing arc of the missile batteries is only 105 degrees.)

[5] In case of AGM-88 HARM threat I consider this quite suicidal operational method.

- None of the equipment of S-300/400 has any armor therefore using as an army SAM moreover, it does not have nuclear, chemical and biological protection which is a requirement for army units.

Regardless of the listed issues and restrictions with a tricky and wise way can be improved the mobility of the S-300PMU. The missile battery can be split up two parts. In the first group are assigned the 5Ya62 antenna system in deployed state which provide the data link connections, in the second group can be the ST-68U (Thin Shield) radar, both groups can have 2-2 launcher sections with 24-24 missiles. (Launcher sections cannot be split up freely, see later at more detailed description of the PMU variant.)

In this case only the RPN moves between the two vehicle groups. In both pre-made deployment site is possible to reach 5 minutes readiness.[6] While the RPN operates on one pre-made site, another vehicle group can move. Of course this provides only capability against medium and high flying targets because NVO deployment time is 90 minutes and is only one for each missile battery. Even are two pre-made sites only for one can be deployed the NVO, after leaving the first site on another the NVO is not available for a very long time.

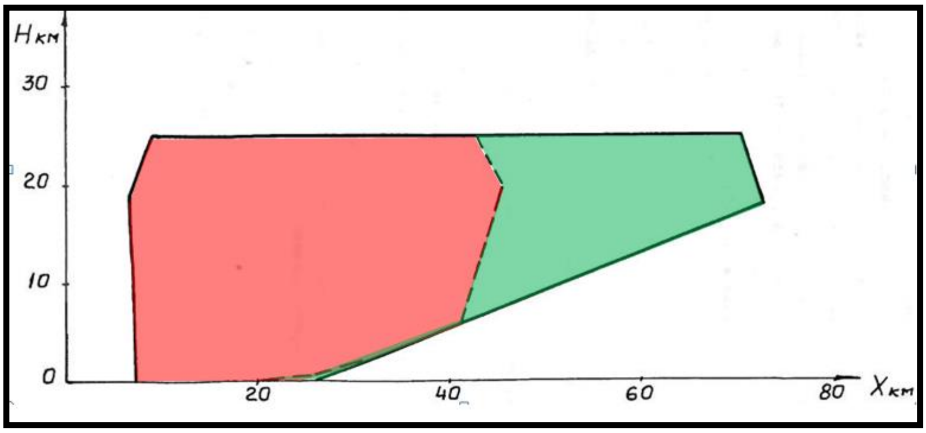
For Soviet S-300 variants the data link connection to automatized command posts outside of the regiment/brigade level (up to theater/front level) is supported by the 55K6S, the command post of the missile battery therefore 5 minutes readiness time is always possible against med/hi flying targets.

Following the structure, organization and the radars of the S-300 is worth to say some words about missiles and the engagement zone of the system. Both the radars and missiles determine the engagement zone and the parameters of the targets.

At first step is important to understand the totally different missile flight path comparing to all previous PVO or even army SAMs. For S-75 and S-125 system the RCG guidance and the guidance antenna and the target illumination mod restricted the flight path of the missiles. They always had to be close to the imaginary line which connects the fire control radar and the target, within the azimuth limitation of fire control radar. (For Divina this was 7x7 for Volkhov 10x10 degrees, see in the description of S-75 SAM family). For the S-200 family the SARH guidance and the digital computers and autopilot of the missile made possible to guide the missile much more freely depending on the parameters of the target, because the missile guided to target itself, the fire control radar just provided the target illumination and before the launch determined the guidance profile and thrust profile for the missiles.

The S-300 (as well as a Patriot) are literally ballistic missiles which mid- and terminal phase corrections. It means the leading and the impact point is determined at the moment of the launch and during the boosting phase missile aims and flies towards this calculated impact point. During mid and terminal phase correction is possible in case the target is maneuvering, but literally anytime can be done changes in the “core” ballistic flight path if it is necessary, aerodynamic control is available even at very high altitude because of the high speed of the missile.

[6] Der Fla-Raketenkomplex S-300PMU in der NVA, page 99.



Above is the engagement zone of the S-300PT with 5V55K (red) and 5V55R missiles (green + red) zones. [7]
(Target offset distance is 0 km.)

Above on the drawing is clearly visible the difference between the different type of missiles and guidance. The 5V55K had only 47 km engagement zone (slant range counts not the projected distance on ground), the red region displays this on the diagram above. The more advanced 5V55R had 75 km range with SAGG guidance its engagement zone is the composition of red + green regions on the drawing above.

The diagram shows similar restriction to early S-200 missiles, the engagement zone is restricted against low flying targets because the effect of the air friction heat on the missile was not solved at that time. This was the negative side effect of the large missile speed. Because of quick demand response against low level CM the S-300PT could be deployed but low level engagement zone was limited about 30 km, the ***guaranteed*** (this word is very important, see later) engagement zone above 30 km distance was higher than the radar horizon. Against higher flying targets the maximal engagement distance was limited by the heating issue not by the guidance or missile kinematics. (Because of this S-200 system remained in service for a very long time, the last S-200 Dubna was dismantled in 2007.)

In the following – and also all previous engagement zone description – the displayed engagement zone mean the guaranteed engagement zone as have been explained in Chapter 5.

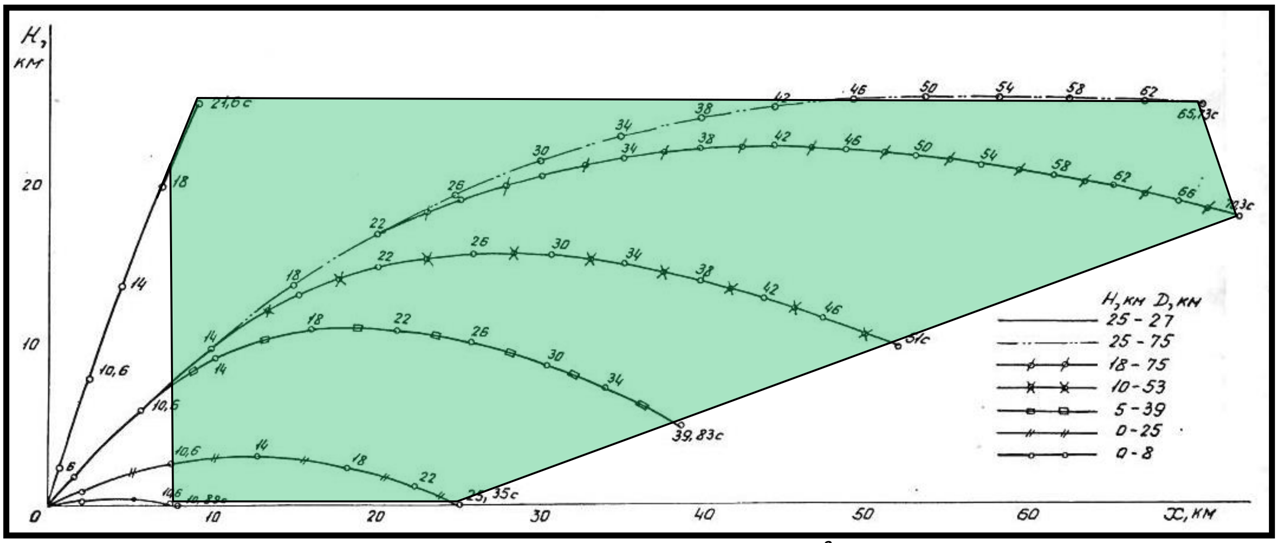
Because of the missile air friction and heat issue even deployed on flat terrain the engagement zone was limited and of course in case S-300 could be deployed on a hill at this point did not provided larger guaranteed engagement zone. In idealized case (flat terrain without obstacles) the engagement would be possible about up to 35 km, but zone above a this distance shows about 4-5 km min. engagement altitude. With 5V55R missiles up to a certain distance intercontinental bombers could be attacked at 10-12 km altitude.

This engagement zone limitation was not a big issue at defense of Moscow because in the late ‘70s it was a very theoretical case a B-52 with only nuclear bombs, AGM-28 and CMs were more advanced CMs existed for a good reason. With some limitations even the S-300PT could down such old fashioned intercontinental bombers, or AGM-28s and also the new CMs. (AGM-28 was phased out in 1976.)

[7] http://historykpvo-2.ucoz.ru/index/0-13;
Система зенитного управляемого ракетного оружия "Орша". Технические предложения. 1978 page 24. This and following diagrams came for the documentation of the SAM system “Orsa” which never entered in service but was designed using the same missiles.

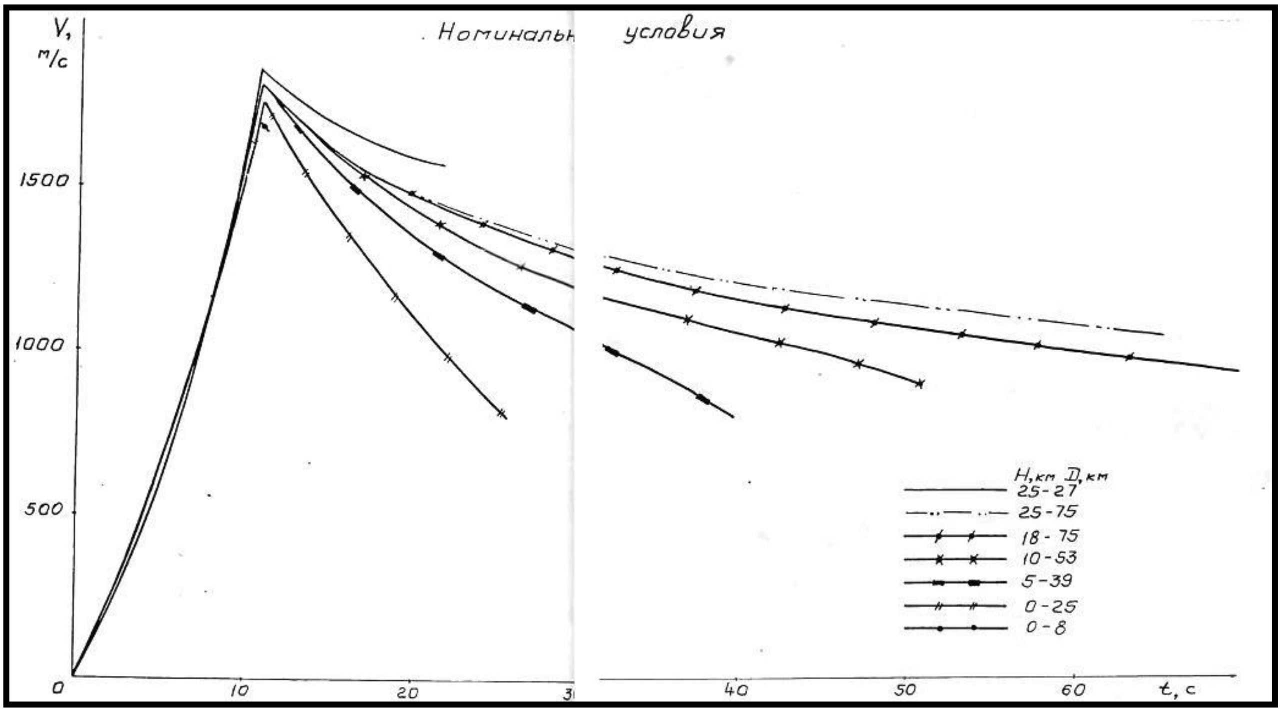
The engagement zone limitation because would be judged differently in this state in WPACT countries where tactical fighters could be potential targets, against them the limitations means much more reduced combat capabilities.

On the diagram below the engagement zone of S-300PT-A1 is displayed with measured missile trajectories on test range, the values shows the flight time in seconds. (H is altitude, D is distance)



Above is the engagement zone of the S-300PT with 5V55R missile. [8] ***(Target offset distance is 0 km.)***

On the drawing above is visible how fast the missile comparing to missiles of S-75/125 family. At 25 km distance the duration of the flight is only 25s which considering the ballistic path it mean a bit above 1 km/s average speed, while the burnout speed, only at very high altitude was M3.0 the best missile of the S-75M Volkhov. Against higher flying targets the average speed of the 5V55R is above Mach 4. The burnout speed of the missile depending or missile trajectory is about 1.8-1.9 km/s



Above are the measured time-speed data of 5V55R missiles in the same cases as the drawing above. [9]

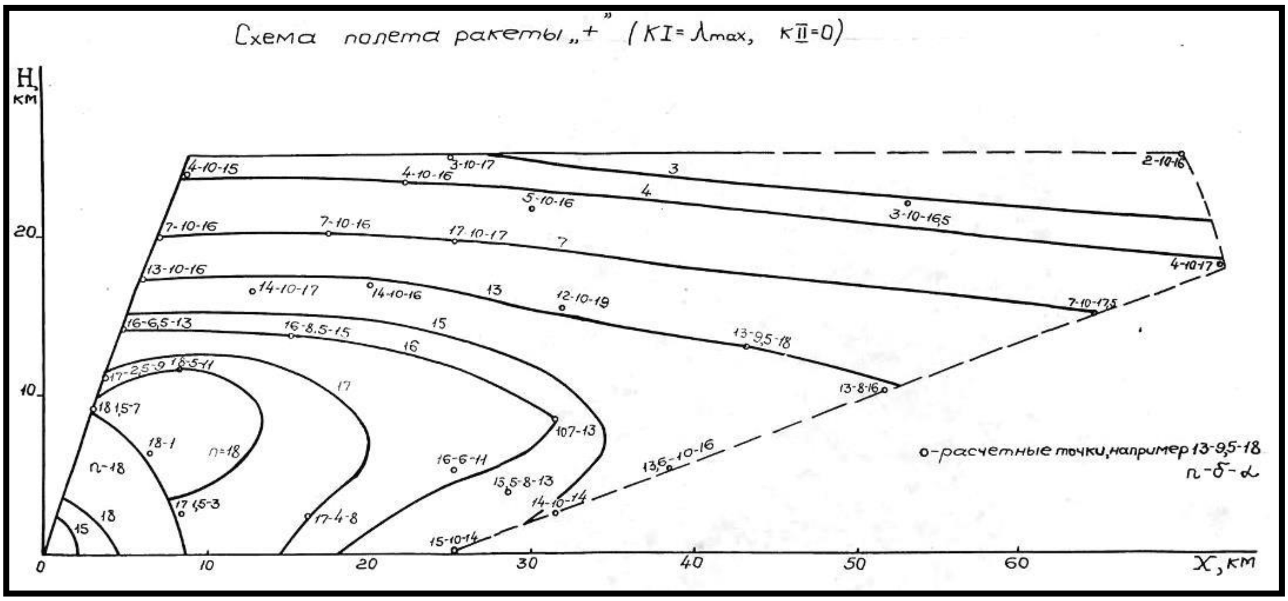
[8] http://historykpvo-2.ucoz.ru/index/0-13

Система зенитного управляемого ракетного оружия "Орша". Технические предложения. 1978; 45.oldal

On the drawing on previous page are the measured time-speed data of the previously shown missile trajectories. The following main observations can be done:

- The single stage rocket engine burnout time is about 11 seconds; the average axial acceleration of the missile is 19G.
- Against a low level (30 m) CM at 25 km distance the speed is 800 m/s, burnout speed is 1800 m/s- The missile decelerates about 14 seconds, the average axial deceleration is 7G. Both the acceleration and deceleration are good markings the high drag force which causes the heat issues.
- At the edge of engagement zone (right upper corner of the diagram) is still about 1200 m/s, close to Mach 4. The top of the ballistic trajectory is close to the maximal altitude of engagement zone. The missile at this point still does not lose altitude the deceleration is very small. The kinematic range of the missile is far larger what the radars or the heat issues define. With longer range radars and more heat resistant missile nose dome material the engagement range can be greatly extended.

The missile trajectory and the time-speed characteristics of the S-300 are strongly different. For Berkut, Diva, Volhkov and Neva the rocket engine run almost during the whole trajectory, the passive phase was very short and missile turning capability was limited as missiles decelerated. In passive phase maximal target speed was only about 300 m/s. Only the S-200 had similarity with S-300 at very long range cases where missile climbed to very high altitude (25-40 km) and after about 60 seconds the rocket engine stopped and could have very large passive trajectory phase without running engine. Comparing to these older systems the active phase of the missiles is very short only 11 second while even with 75 km range the flight duration is 65-70 seconds, but as we can see later the boost stage is not different regardless the engagement distance is 200 km or higher. Regardless of the short engine operational time the maneuverability of the new missiles of the S-300 was far better than any other previous PVO SAM system.



Above is the engagement zone and maximal G values of the 5V55R missile. [10]

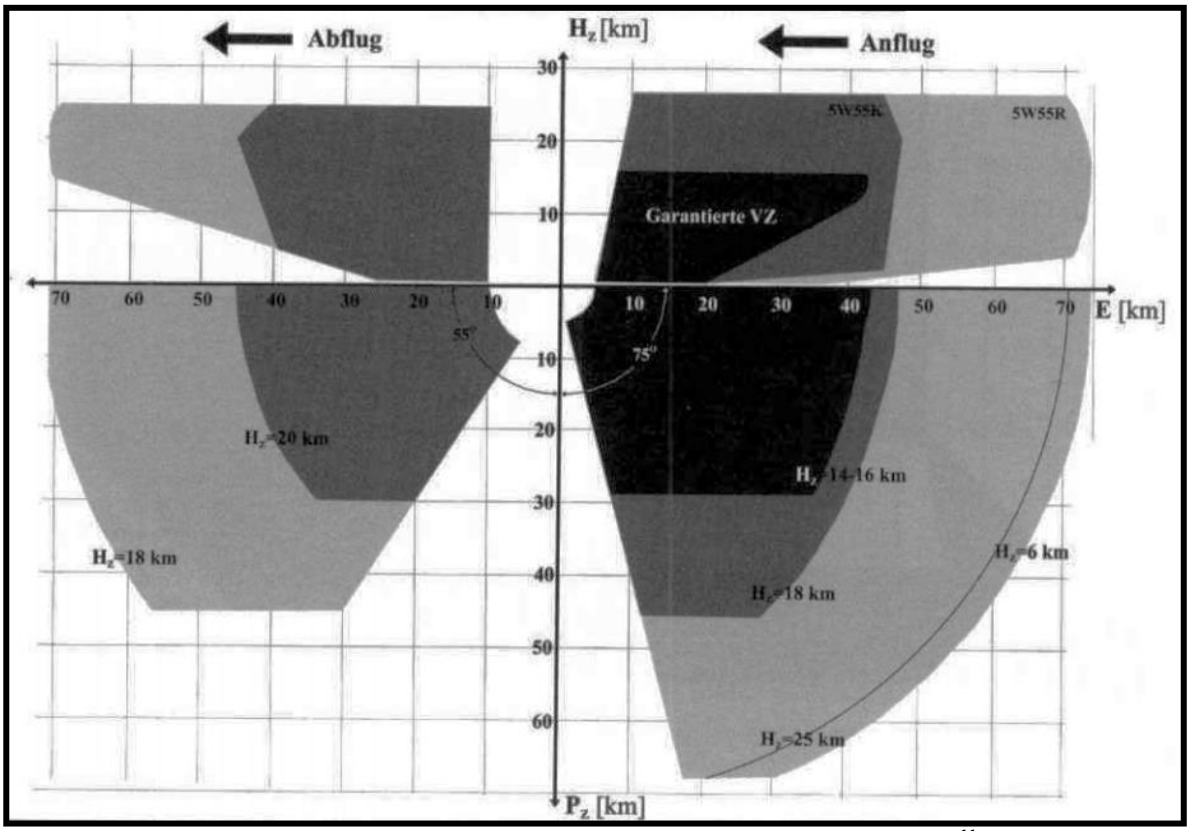
[9] http://historykpvo-2.ucoz.ru/index/0-13;
Система зенитного управляемого ракетного оружия "Орша". Технические предложения. 1978; 46.oldal

[10] http://historykpvo-2.ucoz.ru/index/0-13
Система зенитного управляемого ракетного оружия "Орша". Технические предложения 1978, page 66.

On the drawing above the in the three number group the first value shows the maximal available G, the turning capability of the 5V55R missile. At the maximal engagement range (right upper corner) the maximal G value is only 2G. This is the reason (see later) why is limited the maximal engagement altitude of the PMU1 variant above 80 km distance with 48N6 missile. The missile literally cannot perform any turn above this altitude. This does not mean missile cannot fly above the engagement zone in case of very long range engagement. The trajectory can be above 25 km in mid phase but in this phase is not able to turn but in terminal phase when missile comes back to denser atmosphere is able to turn again and can make the necessary adjustments for the hit.

On the drawing is visible against tactical fighters the missiles of S-300 have better kinematics than all previous missile had considering all PVO SAMS. The 11 second burnout time of the rocket engine carries a very good side effect, in the terminal phase missile is invisible comparing to Divna/Volkhov or Neva which produced very strong smoke during their most of trajectory which made possible to see them and pilots could dodge the missiles. Against 5V55R or any other S-300 missile the kinematic defeat of all currently used fighters (2018) is impossible because the pilots have no idea when should perform the turn. (S-200 also had this feature at long range and high altitude engagements.) Even if pilots somehow knew the position of the incoming missile the kinematics of them is so good that change of successful evasion is close to 0 in most of cases because it requires so precise timing, good relative position, altitude and speed from the pilot and airplane.

From the beginning within the limitation on the engagement zone (EZ) S-300 was way beyond the capabilities of S-25/75/125/200 systems. Only the Vega had larger EZ until the arrival of S-400 (2007), only and the Dubna had larger EZ (300 km) until developing the active radar guided 40N6 missile. (40N6 still not entered into service end of 2017).



Above is the engagement zone of the S-300PMU (SA-10B), late '80s. [11]

[11] Der Fla-Raketenkomplex S-300PMU in der NVA, page 82.

It is time to compare the engagement zone of S-300PMU (SA-10B) with previous PVO SAM systems. (PMU was the offered export variant for WPACT countries.) On the diagram on the previous page the minimal altitude of the EZ shows significant improvement comparing to first 5V55R missiles yet still does not reach the radar horizon, but is very close to it. Radar horizon is at about 350 m altitude at 70 km but the minimal engagement altitude is about 3 km at this distance. On the first engagement zone diagram at 70 km the minimal engagement range was 15 km.

Also should be noted the guaranteed EZ (garantierte VZ) on the drawing. It covers the region where the missile is capable to perform 15G turns, very likely concerning this zone against highly maneuverable tactical fighters.

A minimal engagement distance is larger than S-125M Neva had, this is the consequence of the vertical launch mode and very high initial acceleration, but comparing to 17 km of Vega the 4 km minimal engagement distance was a big leap ahead.

Regardless how advanced was the S-300 comparing to all previous PVO SAMs it had its own limitations, not only because of the kinematics of the missiles and radar detection range. Using digital solid state technology and pulse-doppler radar (not CW as Vega) the S-300PT/PS and even the PMU1 had 125 km/h (~35 m/s) radial speed velocity limit for target tracking. Anything below this radial speed cannot be tracked by the RPN.

In the chart below are the different missile types of different S-300 variants with some major minimal and maximal target parameters. The system has backward compatibility; in theory even the S-400 can use for example the 48N6 missile type.

SAM system type	***Missile type***	***Missile weight***	***Missile range***	***Missile eng. altitude***	***Target speed***
-	-	*kg*	*km*	*km*	*km/h* *m/s*
Sz-300PT (SA-10A)	5V55K	1480	5-47*	0,025-27*	1200m/s
Sz-300PT-1A (SA-10A)	5V55R **5V55S**	1660	5-75*	0,025-27*	1200m/s
Sz-300PS/PMU (SA-10B)	5V55R	1660	5-75*	0,025-27*	1200m/s
Sz-300PM/PMU1 (SA-20A)	48N6/48N6E **6Zh48**	1800	5-150	0,01-27	2800m/s
Sz-300PM2/PMU2 (SA-20B)	48N6D/48N6E 9M96E 9M96E2	1835 333 420	3-200 1,5-40 1,5-120	0,01-27 0,01-20 0,01-30	2800m/s 4800m/s 4800m/s
Sz-400** (SA-21)	48N6DM/48N6E3 40N6 9M96 9M96D	1835 1893 333 420	4-250 4-380 1,5-40 1,5-120	0,01-27 0,01-27 0,01-20 0,01-30	4800m/s 4800m/s 4800m/s 4800m/s

* Against low level targets EZ is limited, see the explanation previously.

** Original designation was S-300PMU3 only because of marketing reasons was changed to S-400.

The missile types marked with red had nuclear warhead, they had the same EZ as missiles with non-nuclear warhead. It is possible 5V55S was the special variant of 5V55K and was possible to achieve larger engagement range than with "K" variant regardless of RCG limitation in accuracy. Only the overheat issues was the limit for engagement range.

After knowing the most basic limitations of EZ and missiles is worth to say some new features for the S-300 family comparing to older PVO SAMs concerning SEAD and survivability of batteries. Even just suppressing an S-300 battery needs totally different amount of sources considering both quantity and quality. Against AGM-88 HARM (and similar ARMs) the S-300 has partial protection because the system is able to track and launch missiles on incoming ARMs if ARMs have been detected (similar to Patriot). Both S-75/125 had a single target channel therefore in case of detecting ARM literally the only wise way to turn off the radar to survive because was pointless to waste a SAM to shoot down an ARM. So it was quite easy to suppress SAMs in Vietnam era but destroying was another thing.

(In Vietnam only the much shorter range and primitive AGM-45 Shrike and later stage of the conflict AGM-78 Standard was available. AGM-88 HARM is a totally different thing see later in chapter 7.)

Although S-300 batteries which were deployed in USSR mostly did not have to consider ARM threat the S-300 was prepared such kind of threat because of WPACT and possible other export option, in proxy conflict ARM threat was expected for tactical fighters and attack aircraft.

Comparing to RS (radar station) of Patriot the RPN (Flap Lid) was not optimized to search so best chance to detect and ARM launch is in case the RPN has already tacked a target which launches the ARM. The RPN can detect the separation from the aircraft the missile – just as was possible even with SA-75 Dvina is Vietnam – bit besides detecting the launch it is able to track the ARM further along the trajectory thanks to the PESA type RPN radar. Launching a missile on ARM also is possible because S-300 has x6 target channels, so even “sacrificing” one to defend the missile battery is still enough missiles and target channels to deal other threats and targets.

Comparing to S-75/125 is almost impossible to suppress face to face with ARMs the S-300 because the lots of available missiles and target channels, not mentioning the range of ARMs comparing to range of even just the 75 km of 5V55R. Only the AGM-88 can be launched at high altitude outside of EZ of S-300. They best way to deal with S-300 lofting AGM-88 under the horizon. Only problem the NVO radar which scans only low level, so even in such case the survivability of SEAD fighters can be achieved but in theory 360 degree scan radars can provide the necessary time to react ARM threat. But as all things in life S-300 anti-ARM capability has its own limits:

- The RPN has only 105 degree firing arc, so if in the same time lots of ARMs incoming from two very different directions it is possible to bypass the defense capability of the system. AGM-88 HARM can use sidelobes to destroy the RPN, HARM can be used even the launch platform is not targeted by the S-300. A single missile battery can launch missiles one main direction but in case ARMs come from two very different way...[12]
- In optimal case hopefully the RLO (Big Bird) radar of the regiment/brigade is able to detect the incoming ARMs, but this cannot be ensured in every tactical situation because of distance between command batteries and the missile batteries and small RCS of the ARMs. The distance between RLO and HARM in the moment of launch can be 100-150 km; very likely the HARM can be detected from much less distance.

[12] During Operation Allied Force NATO forces assumed the presence of S-300PMU1 (the PMU1 never arrived to Serbia, on Hungarian-Ukraine border custom officials turned back to Russia) the SEAD flights always approach the suppressed region with about 110 degree aspect difference. Even one of the flight could be attacked the another flight was able to launch HARM.

- In case launch under the horizon NVO very likely can detect the climbing HARM because it is designed to find and track at low level CMs which ae similar in size to HARM. Only problem in case of hit and run tactics the NVO deployment time is 90 minutes.
- The export PMU variant did not have the command battery, they could be linked to higher level automatized command posts and had their own 360 degree EW radar the ST-68U (Tin Shield) This change interestingly maybe provided better anti-ARM capability because each missile battery had at from low level to high altitude 360 degree search capability. (But the deployment time of ST-68U is 45 minutes comparing to the data link connection of Russian variant to RLO which is 5 only minutes.)

Regardless of limitations of anti-ARM capability was a totally new level of threat comparing to S-75/125. It requires much more and better HARM to just even being suppressed.

For better understanding the capabilities of S-300 it has to be known the term of “cycle time”. The cycle time concerning of each fire channels and covers duration from the first detection of a target until the impact of the missile the target and evaluation of the impact. The cycle time depends on the target distance. At minimal 7 km distance is 31 seconds; at 75 km is 97 seconds for the S-300PMU (SA-10B) [13] At short distance the cycle time is surprisingly high because calculating target track, IFF, preparation of missiles and other activates are also included. This is why not ten times longer is the cycle time in case of 75 km target distance, at short range not the missile flight time means the bigger part of the cycle time. When the missile hit the target and evaluation happened he cycle restarts for the available target (or missile) channel.

Missiles can be launched with 3 second intervals, so in case of a massive attack just launching 6 missiles on 6 targets requires 18 seconds. Missile preparation and IFF during flying out of the missile is possible which can boost a bit, but is still a limitation.

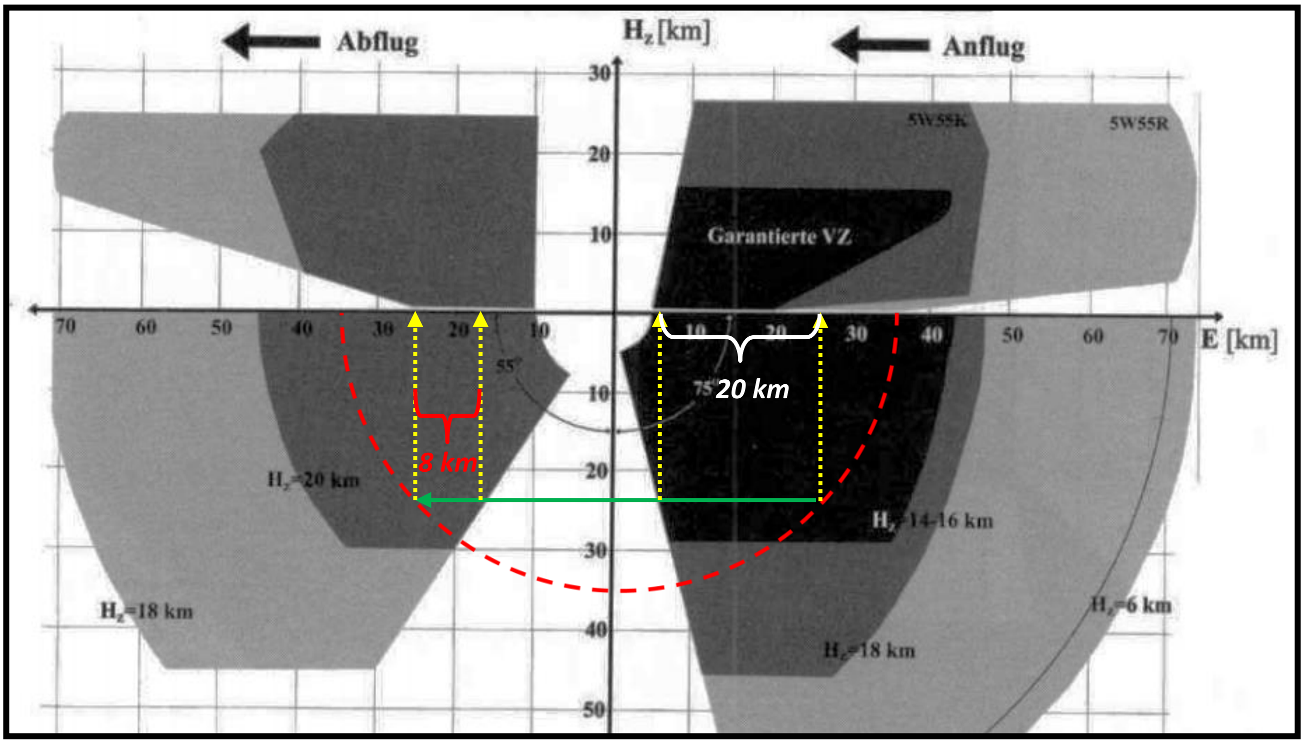
Through a thought experiment we can see and judge the capabilities of the S-300, let’s see what can do against a massive CM attack in idealized conditions (flat terrain without obstacles) and non-restricted low level capability, the missile can be guided until the edge of radar horizon.

CM flying at 30 m is detected by the RPN from 35 km, but the NVO at 45 km can detect first time the first CM, therefore the RPN has information where are expected showing up the CMs under the radar horizon. The missiles can be prepared for launch according to quantity of the incoming targets, but target tracking can be started with RPN only from 35 km.

The flight time of a missile to 30 km is about 20 seconds (see the drawing previously), for the system about 15-20 seconds additional time is needed – depending of the preparation process of missiles, for ex. spooling up the gyroscopes – for IFF, target assignation and before the launch. From the first detection CMs fly about 9 km before the first launched missile hit the first incoming CM, then from this point in every 3 seconds can be hit a CM in case the distance gap is small between the CMs. After each hit or miss a target channel is available again, new cycle begins for the target channel.

[13] Der Fla-Raketenkomplex S-300PMU in der NVA, page 83.

The EZ has its own limitations as already has been described above. In this thought experiment we consider the setup as displayed on the next page.



Above are the engagement zone of the S-300PMU and the trajectory of the incoming CMs. Radar horizon for RPN is marked with the dashed red line

In the experiment CMs arrive in the zone and direction is marked with green arrow, which has about 23 km offset distance. Considering this flight path for CMs they are in the engagement zone for about 20 km after the first detection. In this idealized case about 18 missiles can be guided before they fly outsize of EZ in case CMs fly in dense pack.

In case CMs already has passed beyond the SAM site and missiles are launched behind from CMs targets are in the engagement zone for about 8 km. The low level CW NVO radar does not have radial speed limitation for tracking therefore launching the missiles is possible even before some second RPN have started tracking CM towards to an expected location with terminal trajectory correction but in this phase shooting down more than 3-4 targets is very unlikely.

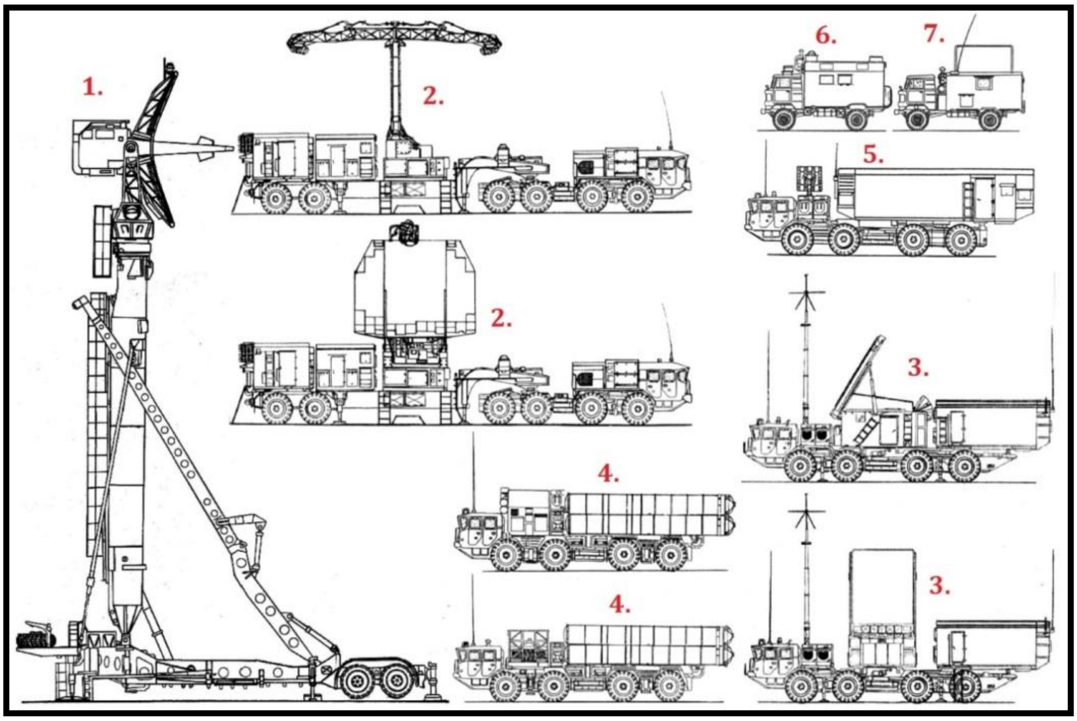
We can conclude from the thought experiment overlapping the EZs is needed between missile batteries to stop a massive CM salvo and is also a good thing in case the pack of CMs tries this on the opposite side of the missile battery, the adjacent missile battery can help in the overlapping EZ region.

Also should be noted the size of overlapping region and the radar horizon itself strongly depends of terrain features and location of the SAM site. A hill close to site can block large region while deploying just a 10-20 meter tall very small hill can extend the detection range of RPN to 40-45 km and 50-55 km to NVO which has very strong impact on the thought experiment was explained above.

In case target tracking is broken regardless of relocking the target (even the older Volkov could do relock) can mean missile is not able to turn in time back to CM or any target. If the target changed its flight

direction while target tracking is not possible with RPN is not possible to guide the missiles after the relock the hit is not ensured.[14]

Let’s back to the history of S-300 family. After the S-300PT the next variant was the S-300PS Volkhov-M6 (SA-10B) which was manufactured between 1983 and 1990. (Volhkov-M6 designation likely was created to confuse intelligence agencies it has nothing to do with S-75 system.) This was the originally planned mobile variant both the missile launchers and the RPN were installed on self-propelled vehicles. From the 70 manufactured batteries 20 were deployed around Leningrad, the rest of PS variant batteries replaced the S-75/125 batteries on other locations.



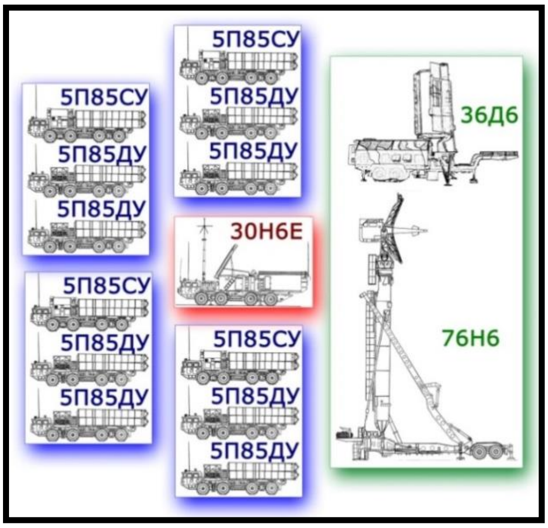
Above are the main items of the 75R6 S-300PS Volkhov-M6 (SA-10B).

1. 5N66M NVO (Clam Shell) low level 360 degree search radar (F5M). Each missile battery has 1 pc.
2. 5N64S RLO (Big Bird) 360 degree long range EW radar (medium and high altitude search radar for the regiment/brigade) (F6 antenna, F7, F8 cabins). Only the command battery has 1 pc.
3. 5N63S RPN (Flap Lid) fire control and missile guidance radar (F1sz antenna, F2 cabin). Each missile battery has 1 pc.
4. Upper vehicle: 5P85S SPU self-propelled launcher (F3S cabin) with x4 missiles (5V55K, 5V55R or 5V55S or combination of these.)
   Lower vehicle: 5P85D SPU self-propelled launcher with x4 missiles (5V55K, 5V55R or 5V55S or combination of these.
5. 5K56S PBU combat command cabin, each launcher has 1 pc.
6. 1T12 geodetic metering truck.
7. KSM command vehicle.

The most striking change comparing to PT variant both missiles and the RPN were installed on self-propelled vehicles. The NVO and RLO because of their size remained on towed vehicles. The basic capabilities of the missile battery basically were very similar to PT, it was just more mobile. The PS was the

[14] Maybe missiles can get target coordinate form NVO but I have doubts about this.

originally planned variant of S-300 the PT was rushed to service because of the fear of quick spread of CMs in US arsenal.

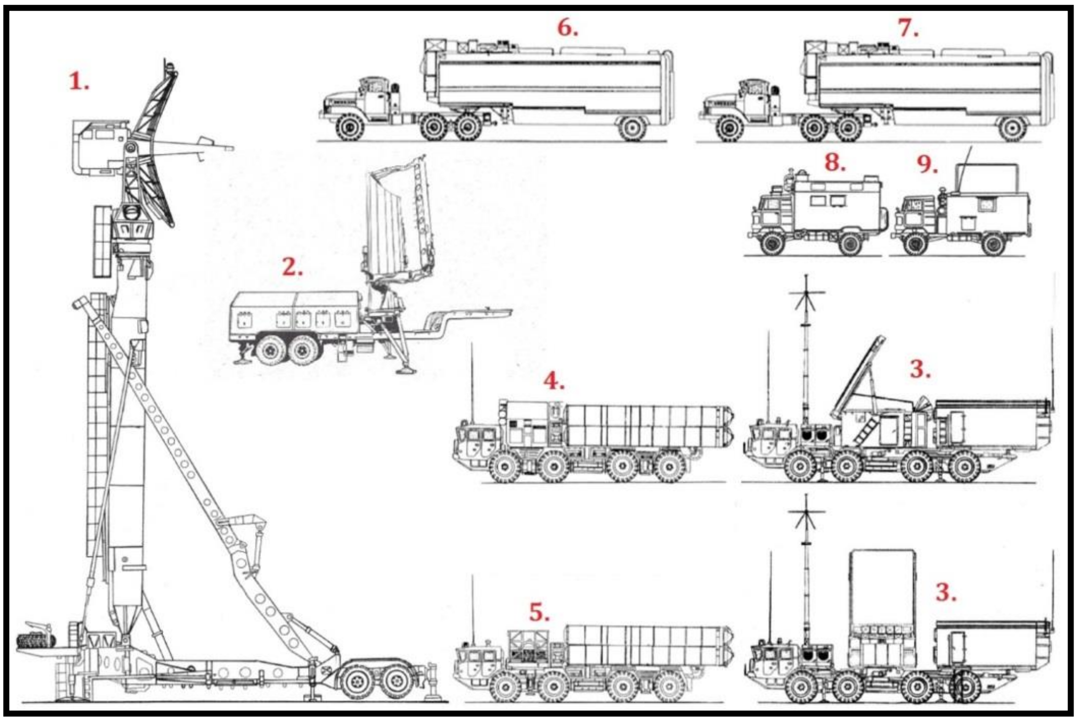


The last 6 batteries of the PS variant made for export into WPACT countries with S-300PMU Volkhov-M6 (SA-10B) designation. In 1989 Bulgaria and East Germany acquired 1-1 batteries, in 1990 Czechoslovakia 1 battery. At this moment happened the political revolutions in the Eastern Bloc countries. Because of this political change the x2 Hungarian and the single Poland S-300PMU battery were not acquired, the orders were cancelled.

Following the German reunification the single S-300PMU battery was given back to Russian. With this and the other not shipped PMU variants were sold to China in 1994, for the 4 batteries China paid 220 million USD.

The crew in Hungary got the training and even the barracks and the sites were prepared only the equipment of the SAM unit missed before the collapse of WPACT. Hungary tried to acquire in exchange for Russian debt but leadership of Russian denied the request and instead S-300PMU offered 22+6 MiG-29 fighters.

The structure and equipment of PMU was strongly different from any other S-300 variant. Because of financial issues the regiment/brigade battery simply was abandoned with RLO and the PBU. Because one WPACT country typically had only 1 S-300PMU it would be pointless and expensive to support them with RLO, their operational method were similar as S-75/125. The missile batteries could have data link to higher level automatized command posts but for 360 degree medium and high altitude search PMU got an EW radar, the 36D6 ST-68U (Tin Shield) radar. The main items of an S-300PMU battery are on the image below:



Above are the main items of the 90Z6 S-300PMU Volkhov-M6 (SA-10B).

1. 76N6 NVO (Clam Shell) low level 360 degree search radar (F5MU). Each battery has 1 pc.
2. 36D6 ST-68U (Rin Shield) medium and high altitude 360 degree search radar (F5MU). Each battery has 1 pc.
3. 30N6E RPN (Flap Lid) fire control and missile guidance radar (F1U antenna, F2U cabin). Each missile battery has 1 pc.
4. 5P85SU SPU self-propelled launcher (F3U cabin) with x4 missiles (5V55K or 5V55R or combination of these.)
5. 5P85D SPU self-propelled launcher with x4 missiles (5V55K or 5V55R or combination of these.)
6. 26M6 PB, combat post of the 5S99M Senezh automatized commanding system.
7. 27M6 DBPU, auxiliary combat post of the 5S99M Senezh automatized commanding system.
8. 1T12 geodetic metering truck.
9. KSM command vehicle.

The designation and the name of the launchers is a bit confusing, following designation the abbreviations mean the followings, the SU and DU characters are part of the designations:

- PU – launcher
- BPU – towed launcher
- SPU – self-propelled launcher

These labels have very important meaning. The SU and DU self-propelled launchers ae not identical, because of this difference are existed launcher sections. The DU (ду) only with cable connection can communicate with RPN but only via SU (су) vehicle, the DU vehicles are not functional without SU. One launcher section is built up from 1 x 5P58SU + 2 x 5P58DU, are x4 sections in a missile battery. The SU is capable to make connection with RPN via cable and radio either. This kind of difference from PM/PMU1 variant eliminated, from that variants the RPN could connect any quantity of launchers.

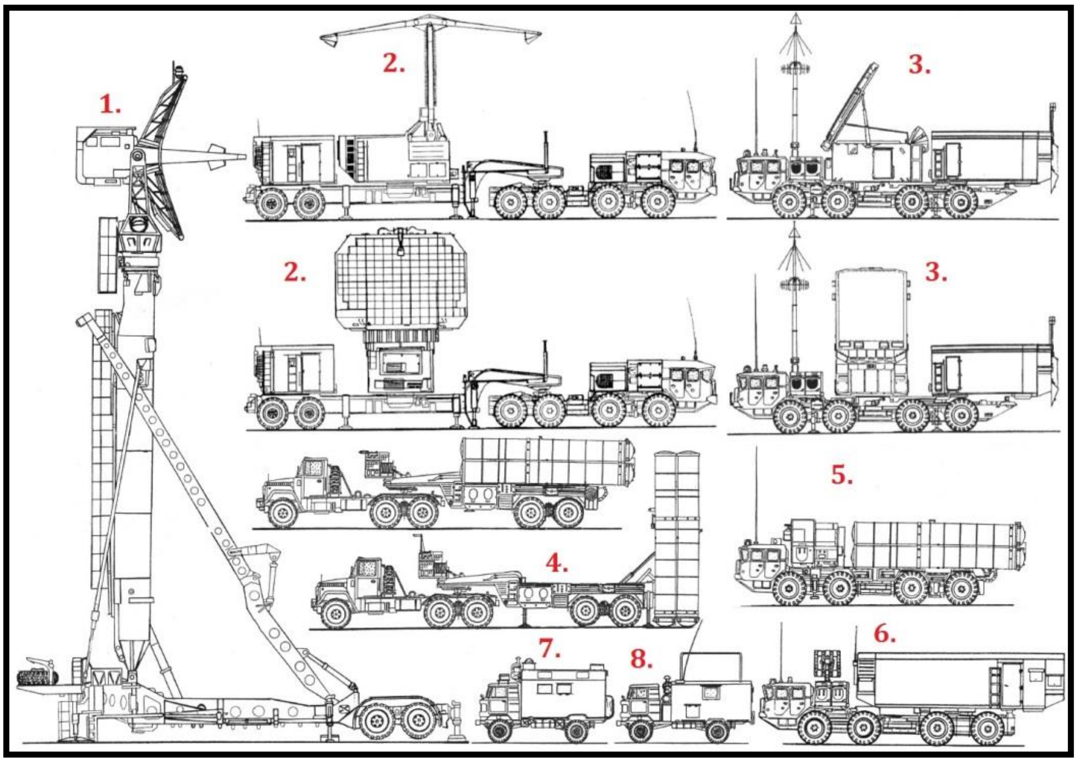
The next variant in the evolution line was the S-300PM Volkhov-M6M (SA-20A), the export variant designation was S-300PMU1. This variant was completed only after brake up of the USSR and WPACT.

Because of financial issues of Russian comparing to tradition of Cold War much earlier was offered for export. 35 missile batteries were manufactured between 1993 and 1996; the last 8 batteries were manufactured with S-300PMU1 Volkhov-M6M (SA-20A) designation for export. China bought 4 batteries for 462 million USD (as debt repayment), Greece and Vietnam acquired 2-2 for 230-230 million USD.

(Every used with command battery so the Greece ad Vietnamese units are regiments only with 2x missile batteries.)

From the 27 remaining batteries 20 batteries were deployed into the inner SAM circle around Moscow. (The outer ring is abandoned some sites now are residential areas.) The last 7 S-300PM with the 56 replaced S-300PT batteries forwarded to remaining S-75/125 sites which were phased out in 1996 which meant and end of an era, the last first generation PVO SAM batteries, the icons of the Cold War retired from active duty on their motherland.

The S-300PM/PMU1 similar to all previous S-300 has x6 target and x12 missile channels, but with the new 48N6 missile the engagement zone was extended to 150 km, the minimal engagement altitude against close low level targets is only 10 meters.



Above are the main items of the 35R6 S-300PM Volkhov-M6M (SA-20A).

1. 76N6 NVO (Clam Shell) low level 360 degree search radar (F5MU). Each missile battery has 1 pc.
2. 64N6 RLO (Big Bird) 360 degree long range EW radar (medium and high altitude search radar for the regiment/brigade) (F6M, F8M cabins). Only the command battery has 1 pc.
3. 30N6 RPN (Tomb Stone) fire control and missile guidance radar (F1M antenna, F2M cabin). Each missile battery has 1 pc.
4. 5P85T PU towed launcher with x4 missiles (48N6, 6Z48, 5V55K, 5V55R or 5V55S or combination of these.)
5. 5P85SM SPU self-propelled launcher with x4 missiles (48N6, 6Z48, 5V55K, 5V55R or 5V55S or combination of these.)
6. 54K6 PBU combat command cabin (F9M), each launcher has 1 pc.
7. 1T12 geodetic metering truck.
8. KSM command vehicle.

The S-300PM/PMU1 can have towed or self-propelled launchers either. They are not applied both in a single battery. The batteries around Moscow typically used towed launchers which replaced the PT variant with towed launchers. The self-propelled launchers are good for the “hit and run” tactics which are more important for export variant users. The list below shows the designations of the export PMU1 variant.

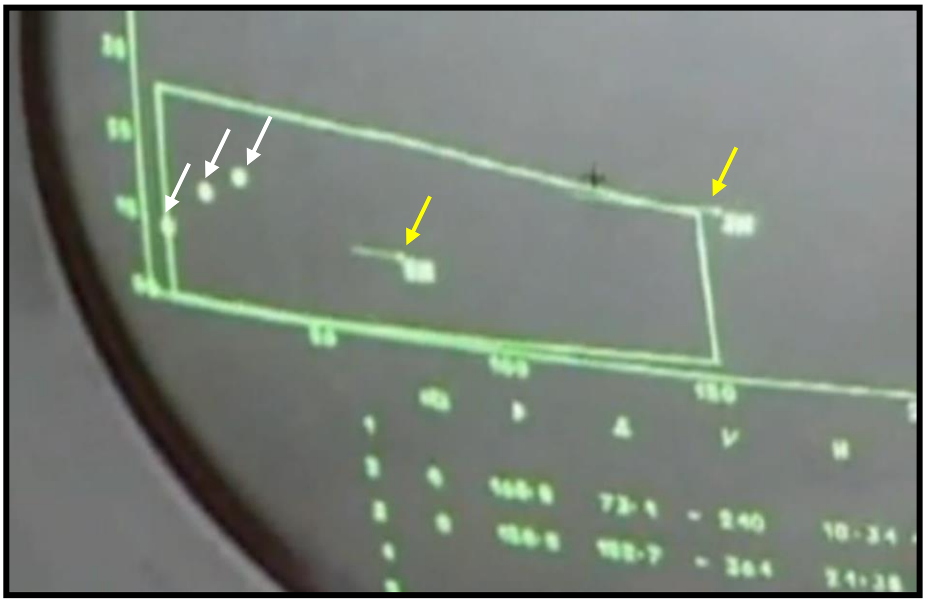
1. 76N6 NVO (Clam Shell) low level 360 degree search radar (F5MU). Each missile battery has 1 pc.
2. 64N6E RLO (Big Bird) 360 degree long range EW radar (medium and high altitude search radar for the regiment/brigade) (F6M, F8M cabins). Only the command battery has 1 pc.
3. 30N61 RPN (Tomb Stone) fire control and missile guidance radar (F1M antenna, F2M cabin). Each missile battery has 1 pc.
4. 5P85TE PU towed launcher with x4 missiles (48N6, 6Z48, 5V55K, 5V55R or 5V55S or combination of these.)
5. 5P85SME SPU self-propelled launcher with x4 missiles (48N6, 6Z48, 5V55K, 5V55R or 5V55S or combination of these.)
6. 54K6E PBU combat command cabin (F9M), each launcher has 1 pc.

7. 1T12 geodetic metering truck.
8. KSM command vehicle.

With the PM/PMU1 variant we are now in the mid-late ‘90s. At this point attentive readers can notice even after 20 years of introducing the S-300PT the engagement range still did not reach not the S-200 Vega (250 km), but even the S-200 Angara had slightly higher (160 km) range. For replacing the S-200 Vega and Dubna the Russian financial collapse in 1998 delayed for another decade.

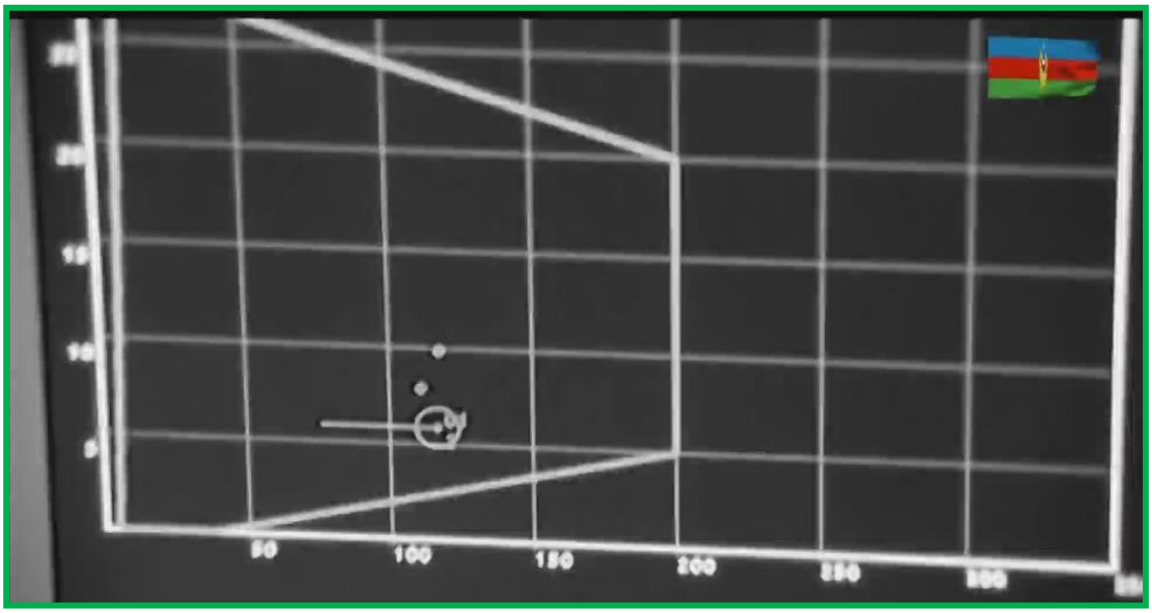
At this point is worth to talk a bit more about limitation of the engagement zone and missiles. Regardless of the size and weight of different missile variant remained almost unchanged. Since the 5V55R the weight increased only with about 100 kg from ~1800 kg to ~1900 kg and even the most advanced variants keep this weight, while the maximal engagement range increased from 47 km to 75 km (PT --> PT-1A, PS, PMU), then 75 km to 150 km (PT-1A, PS, PMU --> PM/PMU1), then 150 km to 200 km (PM/PMU1 --> PM2/PMU2) and finally from 200 km to 250/380 km (PM2/PMU2-->S-400).

For 250 km ballistic range about 1400 m/s, for 380 km ballistic rang is about 1750 m/s burnout speed is needed. Even the first 5V55K missile reached this speed which means never the kinematics of the missile limited the maximal engagement range. On the EZ diagram below for PM/PMU1 the maximal range is defined by a vertical line. This verifies the statement above, the S-25 Berkut or the S-75M Volkhov have different EZ shame at max range which depend on target altitude, which means in terminal phase the missile kinematics is the limit not the guidance or the radar. (For both systems without nuclear warhead 55 km would be a hard limit because of pure RCG guidance.)

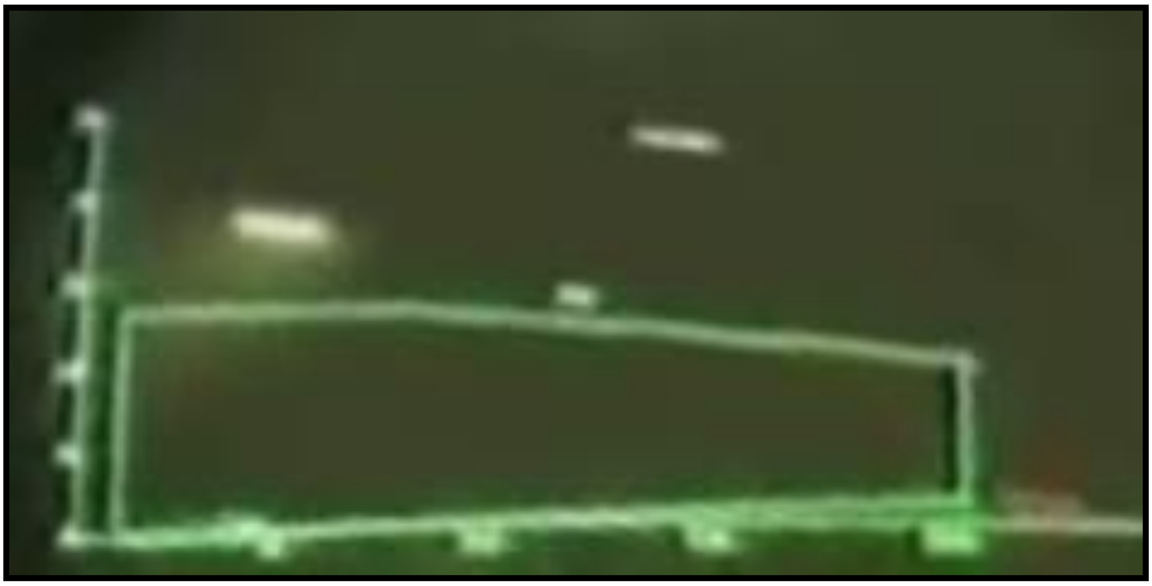


Above is the EZ on the scope of an S-300PMU1 with 48N6 missile. The system tracks two targets (yellow arrows), 3 missiles are on the way to targets (withe arrows). The most distant target is out of EZ at this moment but will be within the EZ when the missile will reach the target. The target parameters are listed below the EZ (offset distance, speed, altitude). On this EZ diagram the EZ reaches the radar horizon, at 150 distance is about 1,5 km the minimal engagement altitude.

What deserves more attention is the minimal engagement altitude. Both for S-200 Vega/Dubna and different variants of the S-300 is visible on EZ diagrams the limitations of the minimal altitude. In case of S-300 we can see EZ sometimes reaches the radar horizon at minimal altitude but sometimes does not.



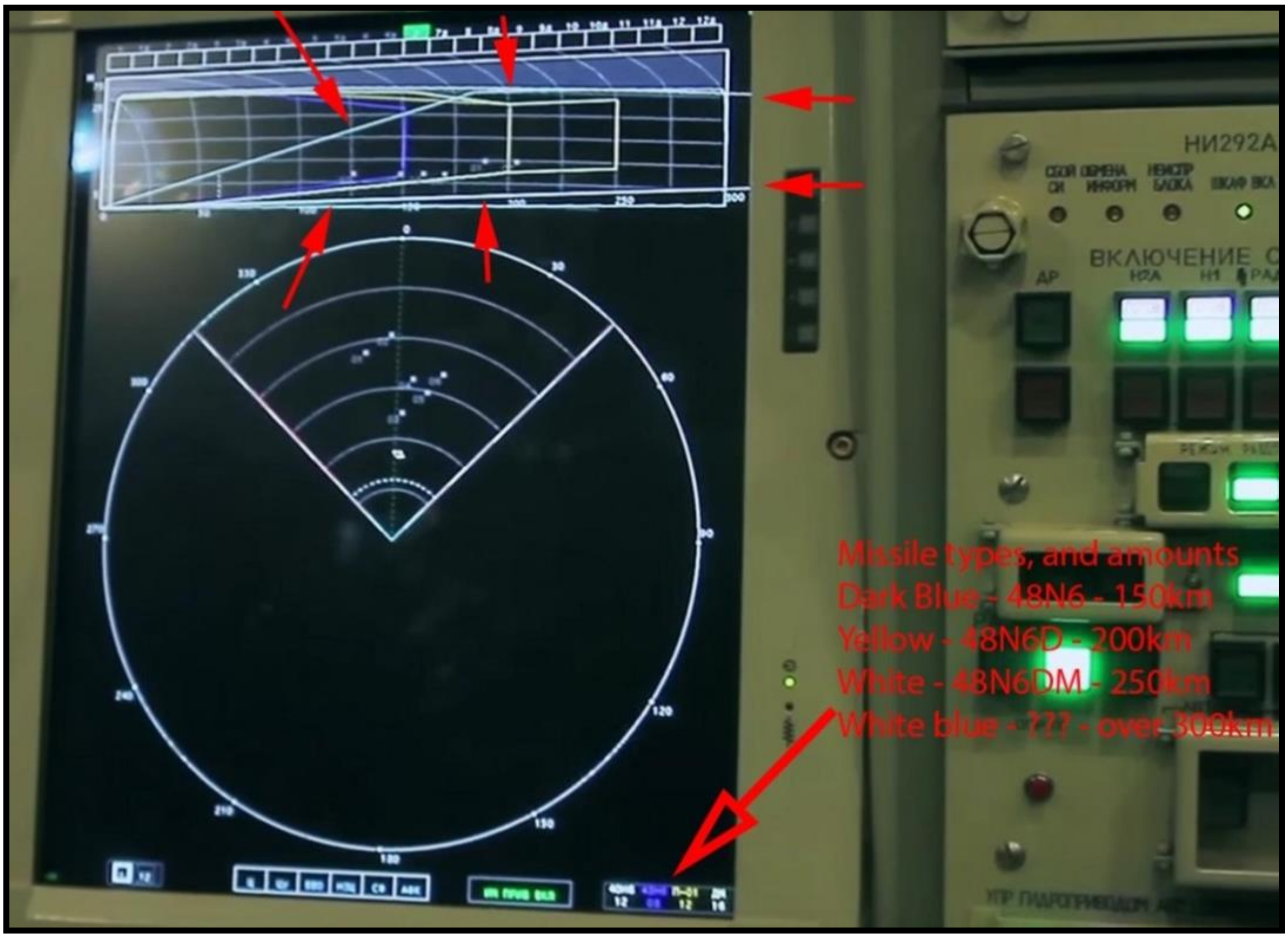
Above is the EZ of S-300PMU2. The minimal engagement altitude at 200 km distance is 5 km while the radar horizon altitude limitation at this distance in only 2 km. The guaranteed EZ does not reach the radar horizon.



Above is the EZ of S-300PMU2, this horizontal distance increment is 50 km, on vertical scale is 10 km. Maximal engagement range is 200 km, but in this case the EZ reaches the radar horizon, at 200 km the minimal altitude is the same as the radar horizon limitations.

On the next page on the same screen are displayed the EZ with 48N6 (150 km), 48N6D (200 km) and 58N6DM (250 km) missiles with S-400 missile battery. It is interesting EZ on this screen never reaches the radar horizon while on at least one image above does it.

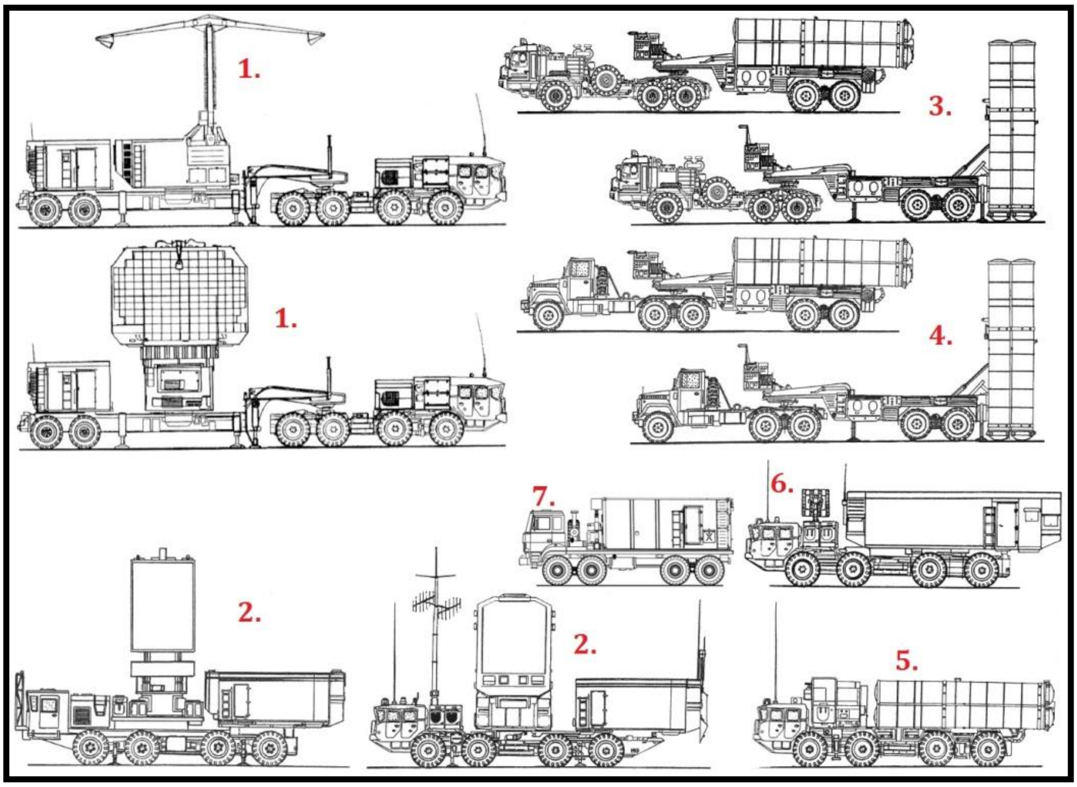
The Russian calculation couples a certain kill of probability for a certain EZ using the experience and results the test and practice launch on test range. Is a chance that 99% zone of EZ changed between the years when the images were captured. What is the point of behind this idea? It does not mean 100% protection flying than minimal altitude of EZ but still above the radar horizon. Nobody can neglect an S-300PMU2 battery flying at 4 km from 180 km to PMU2 battery just because the EZ is a bit higher. The tactical reality nowadays (in my opinion) EZ should be counted in every cases reached the radar horizon no matter what shows the EZ diagram.



Above is the screen of S-400 the engagement zone with different missiles.
Blue-48N6-150 km, yellow-48N6D-200km, white-48N6DM-250 km.

The manufacturing of S-300 family restarted after almost 10 years, it made possible the order of China in 2004, 16 batteries of S-300PMU2 (SA-20B) was ordered for 2000 million USD. Algeria also ordered 4 batteries for 500 million USD, both operators with command batteries. In the upgraded manufacturing facilities between 2007 and 2009 were made the 20 batteries. With the new S-300 a new missile variant, the 48N6E2 (export variant) designed to increase the EZ up to 200 km distance. The target and missile channels remained the same 6/12.

Iran previously ordered PMU2 for 800 million USD, but because of political issues shipping was not possible until end of 2016. The features of PMU2 was give through upgrade to S-300PM this leaded to S-300PM2 variant for Russia, the upgrade started in 2015.



Above are the main items of the 35R6-2 S-300PM2 Favorit (SA-20B).

1. 64N6-2 NVO (Big Bird) low level 360 degree search radar (F5MU). Each missile battery has 1 pc.
2. On left side: 96L6 VVO (Cheese Board), 360 degree search radar. (It scans not only at low level as previously the NVO.)
   O right side: 30N6-2 RPN (Tomb Stone)) fire control and missile guidance radar
3. 5P85TM PU towed launcher with x4 missiles (48M6D, 48N6, 6Z48, 5V55K, 5V55R or 5V55S or combination of these.)
4. 5P85TM-2 PU towed launcher with x4 missiles (48M6D, 48N6, 6Z48, 5V55K, 5V55R or 5V55S or combination of these.)
5. 5P85SM2 SPU self-propelled launcher with x4 missiles (48M6D, 48N6, 6Z48, 5V55K, 5V55R or 5V55S or combination of these.)
6. 54K6-2 PBU combat command cabin.
7. 55K6-2 PBU combat command cabin (regiment/brigade)

Below is the main equipment of the 35R6E S-300PMU2 Favorit (SA-20B):

1. 64N6E-2 NVO (Big Bird) low level 360 degree search radar (F5MU). Each missile battery has 1 pc.
2. On left side: 96L6E VVO (Cheese Board), 360 degree search radar. (It scans not only at low level as previously the NVO.)
   O right side: 30N6E2 RPN (Tomb Stone)) fire control and missile guidance radar
3. 5P85TE3 PU towed launcher with x4 missiles (48M6D, 48N6, 6Z48, 5V55K, 5V55R or 5V55S or combination of these.)
4. 5P85TE2 PU towed launcher with x4 missiles (48M6D, 48N6, 6Z48, 5V55K, 5V55R or 5V55S or combination of these.)
5. 5P85SE2 SPU self-propelled launcher with x4 missiles (48M6D, 48N6, 6Z48, 5V55K, 5V55R or 5V55S or combination of these.)
6. 54K6E2 PBU combat command cabin.
7. 55K6E PBU combat command cabin (regiment/brigade)

For the PM2/PMU the main change beside the larger EZ and different missile replacing the “good old” NVO with the 96L6 VVO 360 degree scan radar.

On the drawing on the previous page the VVO radar is on a self-propelled vehicle, which means the low level search range is reduced because the radar is on not a tall mast. In this case the low level detection range is reduced but the mobility and readiness time is increased comparing to S-300 setup which uses NVO on mast. The missile battery has full 360 search capability from low to high level even the command battery or data link is no available.

It has to be underlined the S-300 is a modular system, is no limitation to sacrifice mobility and put the VVO radar also on a mast similar to NVO. (The mast is 40V6M UV universal mast.) [15] Using ST-68U or the fire control radar (RPN/Flap Lid) is also possible. The radars be can acquired later, for example Vietnam bought S-300PMU1 with NVO radars but later acquired VVO radar to increase the flexibility of their S-300 missile batteries.

It depends only on the operator which kind of radar used on mast. Slovakia has one S-300PMU battery with 2 x 40V6M mast and on training typically both the NVO and the RPN are installed on the mast which does not exclude the option not using mast for RPN and remain on self-propelled vehicle.

Above left is 96L6VVO on 40V6M mast, ST-68U (middle) also on 40V6M, 5N63 RPN (Flap Lid) fire control radar on 40V6M.

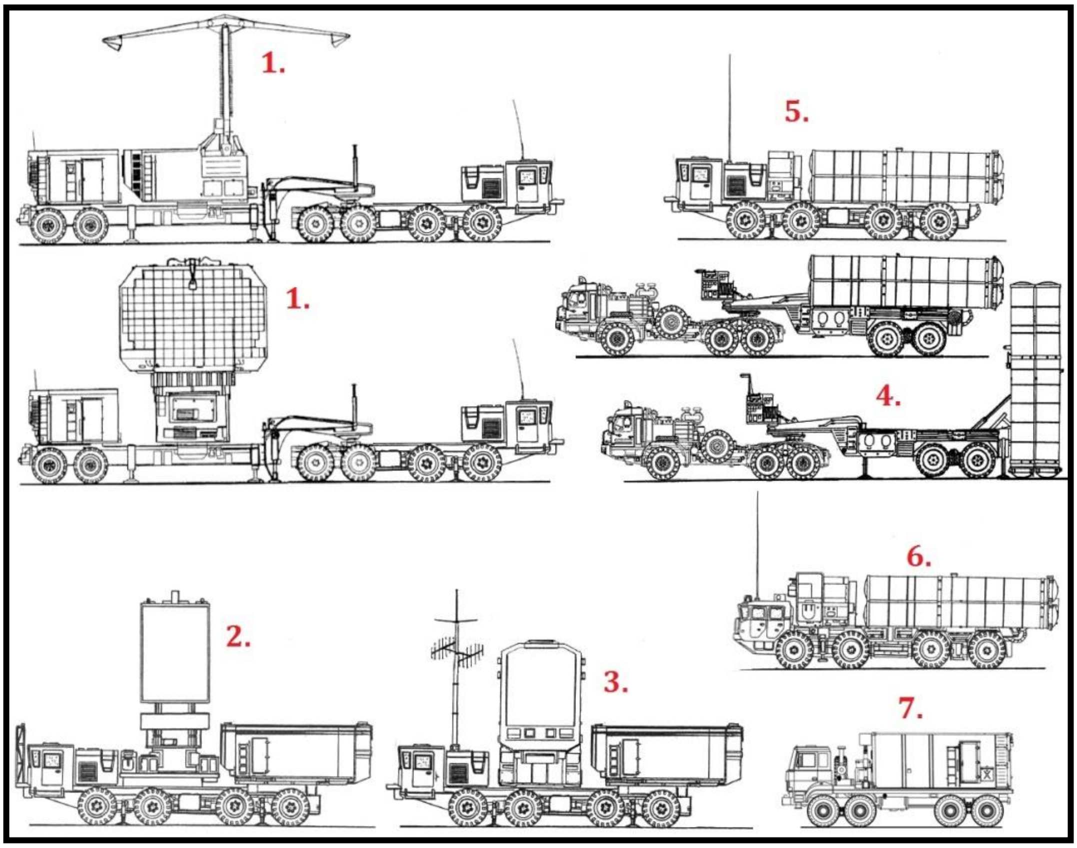
During the manufacturing S-300PMU2 in 2007 and 2009 were completed the first two S-300PMU3 battery for Russia, but because of marketing reasons the designation was changed to S-400 what became SA-21 Triumph. For the S-400 the target channel was doubled to 12 and which new 48N6DM the maximal engagement distance was increased to 250 km. After ending the production of PMU2 since 2011 the production rate of S-400 increased. Until 2020 the plan is manufacturing 56 missile batteries allowing the replacing all the remaining old S-300PT batteries.

Until end of 2016 around Moscow 8 batteries, around St. Petersburg (ex. Leningrad) 4 S-300 missile batteries were deployed, the reset of competed S-400 batteries replaced older S-300 variants around many locations. For the S-400 a new 40N6 missile was designed with active radar homing which allows 380 km

[15] http://www.ausairpower.net/PVO-S/76N6-40V6-1.jpg

maximal engagement range, but until early of 2018 it still has not entered into service. (This is way has only 8 launchers the current S-400 batteries, the 4 remaining launcher will use the 40N6.)

About at 2020 will be available for export the S-400, China has already ordered 6 missile batteries (3000 million USD), India ordered 5 batteries (2500 million USD) and Turkey 4 batteries (2500 million USD).



Above is the 40R6 Sz-400 (S-300PMU3) Triumph (SA-21)

1. 91N6 RLO (Big Bird) low level 360 degree search radar (F5MU). Each missile battery has 1 pc.
2. 96L6 VVO (Cheese Board), 360 degree search radar. (It scans not only at low level as previously the NVO.)
3. 92N6 MFR (Grave Stone) multifunction radar.
4. 5P85TM PU towed launcher with x4 missiles, 48M6DM, 48M6D 48N6, 6Z48 or combination of these.
5. 51P6 SPU self-propelled launcher with 4 x 40N6DM or 16 x 9M96D missiles or combination of these.
6. 5P85SM2 SPU self-propelled launcher 48M6DM, 48M6D 48N6, 6Z48 or combination of these.
7. 55K6 PBU combat command cabin.

Below is the main equipment of the 40R6E S-400E Triumph (SA-21):

1. 91N6E RLO (Big Bird) low level 360 degree search radar (F5MU). Each missile battery has 1 pc.
2. 96L6E VVO (Cheese Board), 360 degree search radar. (It scans not only at low level as previously the NVO.)
3. 92N6E MFR (Grave Stone) multifunction radar.
4. 5P85TE3 PU towed launcher with x4 missiles, 48M6DM, 48M6D 48N6, 6Z48 or combination of these.

5. 51P6E SPU self-propelled launcher with 4 x 40N6DM or 16 x 9M96D missiles or combination of these.
6. 5P85SE3 SPU self-propelled launcher 48M6DM, 48M6D 48N6, 6Z48 or combination of these.
7. 55K6E PBU combat command cabin.

The remaining S-300PS are planned to replace with S-350 Vityaz system. The S-350 will have 16 target channels with 120 km range active radar homing missiles (9M96D). Until 2020 producing of 30 battery of S-350 is planned.

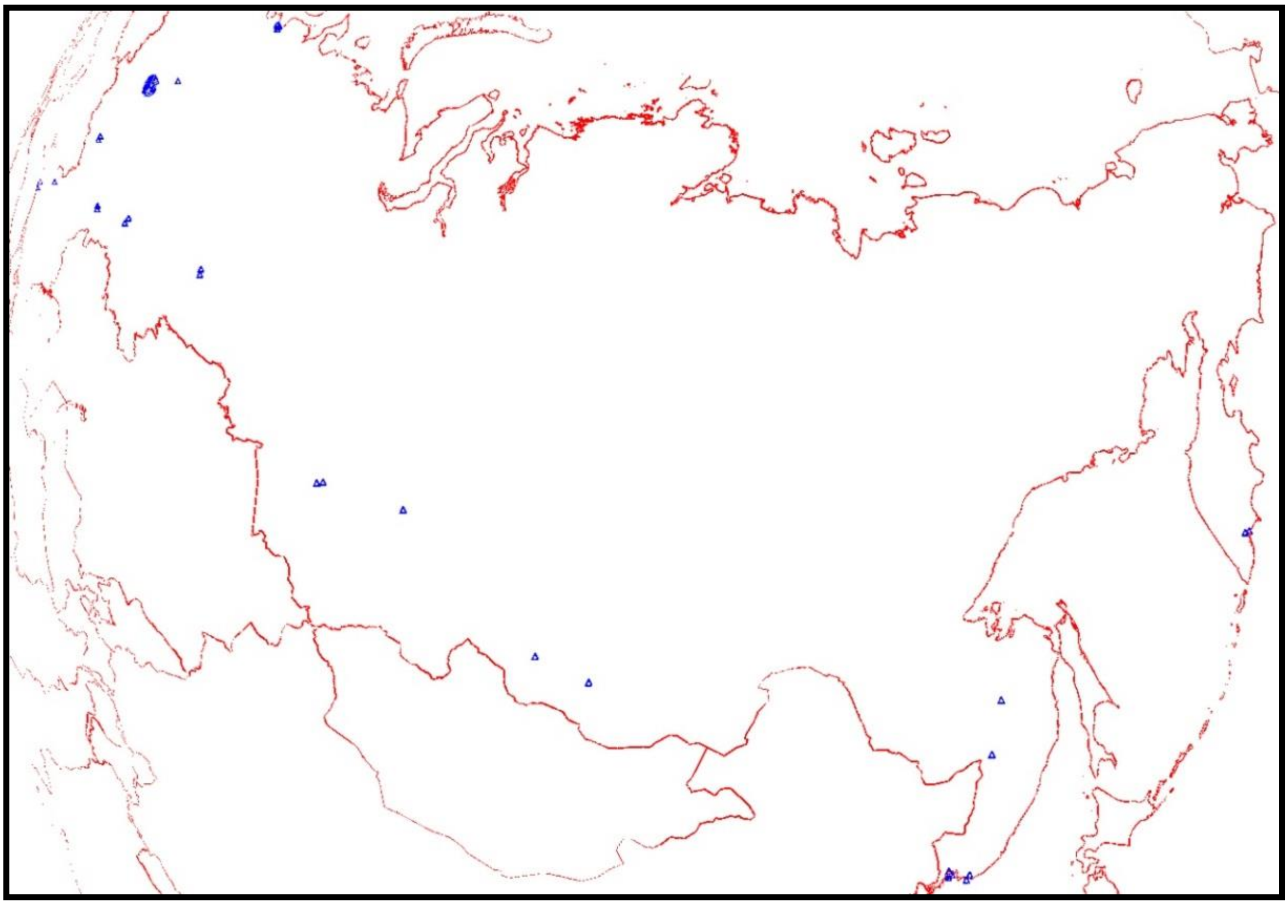
At end of 2016 the Russian air defense had 75 missile batteries in 40 regiments/brigades.

Most important cities • Moscow; 8 S-400, 16 S-300PM • St. Petersburg; 4 S-300PM, 8 Sz-300PS **Other cities** • Yekaterinburg; 2 S-300PS • Samara; 2 S-300PS • Voronezh 2 S-300PS • Kaliningrad; 2 S-400, 4 Sz-300PS • Novosibirsk 2 S-400 • Azov 2 S-300PM • Sokhumi, Abkhazia; 2 S-300PS	**Other cities** • Khabarovsk 2 S-300PS • Szolnvecsnij 3 S-300PS • Irkutsk 2 S-300PS • Nazarovo 2 S-300PS **Pacific Fleet** • Kamchatka 3 S-400 • Vladivostok 2 S-400 • Nakhodka 2 Sz-400	**Black Sea Fleet** • Novorossiysk 2 S-400 • Feodosia, Crimea 2 S-400 **Air Bases of air force** • Engels 2 Sz-300PS • Khmeimim air base, Syria 1 Sz-400 **North Sea Fleet** • Murmansk; 4 S-400, 2 S-300PM, 2 Sz-300PS • Severodvinsk 4 S-300PT

The price tag of each and more advanced variants of S-300/400 became higher and higher. China bought in 2004 for 2000 million USD 16 S-300PMU2 batteries. It is possible to have more modes and more jam protection and 12 missiles channel, but considering only the quantity of batteries – it is almost certain 40N6 ARH guided missiles with 380 km won't be exported – it does not seem logical to buy few S-400.

It seems in many ways to buy PMU2 instead S-400 in case the price of PMU2 remains similar level as was in 2004. The 380 km range of 40N6 missile is just an illusion. Yes, you can draw on maps large 380 km circles, but in reality against most of targets this large range cannot be used because of the radar horizon.

Against targets under horizon the batteries need data from other radars or AWACS planes, without these the engagement range against tactical fighters is just a bit more higher and even at 250 km range the radar horizon is about 4,5 km. The S-400 was designed to operate with A-50/A-100 AWACS which does not have China or Turkey and very likely India export and not 100% Russian made A-50 cannot cooperate with S-400.



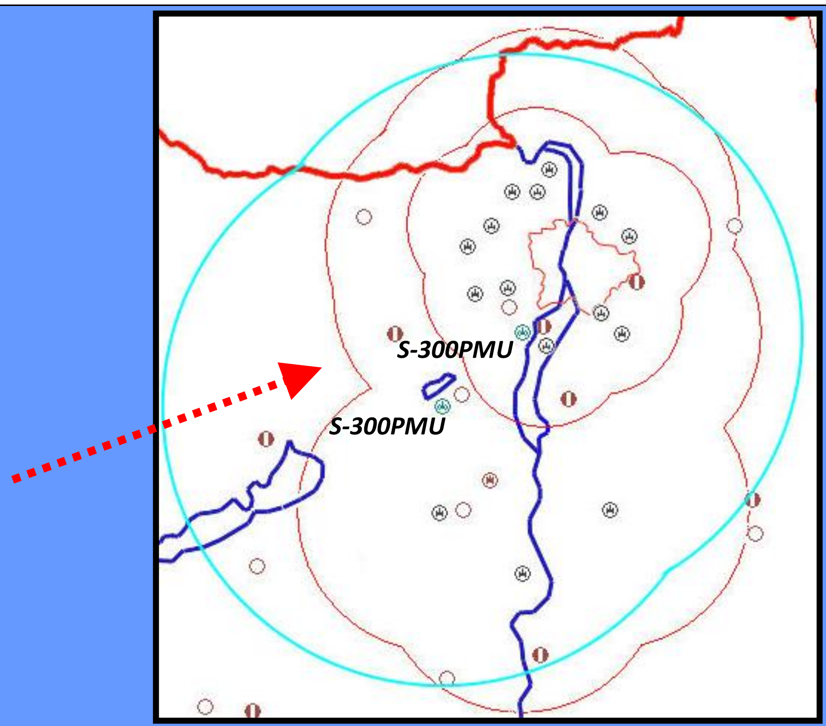
Above are the deployment locations of S-300/400 batteries in Russian without displaying the S-400 in Syria.



RLO (Big Bird) is on elevated podium (above left), the podium is at lowered position (middle), ST-68U (right above) is on the tower.

Around Moscow the deployment was sometimes special. A part of radars (similar what was available for some sites of S-200) were deployed on towers. Not only the RLO but any type of radar vehicles can be deployed on these towers. The vehicle drives on the podium then is lifted up. (Tower has 100 tons of carrying capacity.)

Are towers with two different heights, these were built at the time of deployment of S-300PT in the late ‘70s, in total 10 towers were erected around Moscow. Each brigade/regiment god one for the RLO (Big Bird) radar to improve the low level search capability of the command battery, but the main reason of these towers to put above the RLO of the surrounding forests. It was better elevate the radar than chop down whole forests. When the outer rind of the S-25 Berkut system was dismantled for the inner ring new towers were built. At end of 2016 roughly 12 towers were used, the abandoned older towers are on outer S-25 SAM ring.



For better understanding how powerful and different the S-300 was comparing to older SAM it is worth to examine at least one example, the SAM ring of Budapest. The ring in the late ‘80s consisted 6 x S-75M Volkov and 6 x S-125M Neva batteries, which meat 12x fire channels. At first sight this maybe seems many but this is not so simple.

Because of layout of the range in case of a penetration attack considering very optimistic scenario in case of medium flying targets from a single direction (marked with arrow) is not more than 5-6 target channels could be used against and incoming attack package. This meant 3 x S-75M and 2 x S-125M batteries with 3x6x1 + 2x4x4 = 18 + 32 = 50 missiles on rails ready to launch, considering 5P73 missile launchers for Neva.

According to “rules of engagement” with S-75M three missile salvos with Neva two missile salvos had to be used. Counting this effect without reload in thought experiment 6 + 16 = 24 targets could be attacked but because of very short range of Neva in reality this means less opportunity to launch because fast targets are only a short time for the EZ of Neva. The S-75M was limited by its minimal engagement altitude which was 100 m. Against for example the low level flying Italian Tornados they had questionable effectiveness.

Comparing to this SAM ring a single S-300PMU batter had only 105 degree of launch arc, but even the 360 degree coverage the SAM ring as a whole against a single big package only a part of batteries had only any chance to launch missiles at all. Both S-300 batteries (cyan color) would be deployed southeast from Budapest. Because large engagement zone of PMU and 30 meter minimal engagement altitude was not possible to get around none of the old or the S-300 system.

(From south of Budapest on two airbases two MiG-29 regiments were stationed from 1986. Both airbases were defended by 1-1 Neva batteries, Tököl and Kiskunlacháza.)

The 6 target channels and 48 missiles ready to launch meant a single S-300PMU had better firepower what the old SAM ring could provide in case a reasonable scenario. The S-300PMU had totally different jamming resistance and the kinematics of missile also was far better, the missiles are faster so the cycle time of fire channels of S-300PMU is lower than old SAMs. The allocation of the 6 target channels were supervised by the single combat command post of the battery itself did not required a higher level automatized command system of the IADS.

(The S-300 defended not only the capital city but the two main sites of the automatized command posts.)

As usual in previous systems below are some video and images about the S-300 family. On the first video with the oldest S-300 we can see the manual target tracking similar to Neva and Volkhov systems, the azimuth and elevation are set with manually set dials.

https://www.youtube.com/watch?v=bk9iqsbzqlY

Deployment of S-300 and missile launches:
https://www.youtube.com/watch?v=R9xEUwJVVVM

Galleries::
http://www.ausairpower.net/APA-Russian-SAM-Radars-DKB.html
http://www.ausairpower.net/APA-Grumble-Gargoyle.html
http://simhq.com/forum/ubbthreads.php/topics/4319869/1